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THE USE OF THE CIVIL RESERVE AIR FLEET IN EVACUATION OF 1/1

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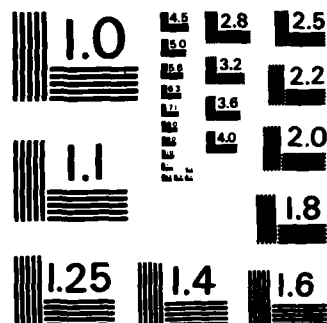
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THE USE OF THE CIVIL RESERVE AIR FLEET IN EVACUATION OF BATTLEFIELD CASUALTIES

An Evaluation

Richard E. Thomas, Ph.D.

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NOTICES

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.



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19. ABSTRACT (Continue on reverse if necessary and identify by block number) In an attempt to bring some relief to the strategic military aeromedical evacuation system, the suggestion has been made that aircraft belonging to the Civil Reserve Air Fleet (CRAF) could be used. The potential for utilization of the CRAF for medevac is excellent, due to the size and composition of the fleet. With 323 airplanes in the long-range international part of the CRAF, all of the wartime troop deployment and medevac demands could be met, and the ability of the strategic airlift system to handle large and oversized cargo would thus be increased. In this study, the call-up of the CRAF for aeromedical evacuation was prioritized, a two-litter stanchion system was designed for the CRAF and/or Military Airlift Command aircraft, and necessary equipment was identified for a carry-on palletized system vs. an expensive aircraft modification system. <i>Revised</i>					
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PREFACE

The aerial transport of battlefield casualties from a remote theater of operations to hospitals in the United States will, during a major wartime contingency, place a heavy burden upon an already overburdened military airlift system. This prospect, coupled with the lack of a plan for alternative means of medical aircvac, is a cause for concern on the part of those individuals and organizations responsible for the care of wartime wounded.

The present system of intertheater aeromedical evacuation (strategic medevac) primarily uses C-141s that have been temporarily reconfigured to accommodate both the seriously ill as litter patients, and the less seriously ill (the ambulatory or "walking-wounded") as sitting patients who are transported upright in seats. This system, however, has numerous shortcomings. For example, the C-141 is not a people-oriented vehicle and lacks most of the amenities found in regular passenger-carrying aircraft. As a result, conditions aboard are not only barely tolerable for healthy people, but can be physically deleterious for the ill and wounded.

To bring some relief to the situation, the suggestion has been made that aircraft belonging to the Civil Reserve Air Fleet (CRAF) could be used in the medevac role. The potential for utilization of the Civil Reserve Air Fleet for medevac is excellent, due to the size and composition of the fleet. In terms of the size, estimates are that the passenger-carrying capability of CRAF far exceeds the projected troop deployment requirements of a wartime contingency. With 323 airplanes in the long-range international (LRI) part of CRAF, all of the wartime troop deployment and medevac demands could be met, and the ability of the strategic airlift system to handle large and oversized cargo would thus be increased. In terms of composition, the LRI fleet consists of 707, DC-8, 747, DC-10, and L-1011 types, with the wide-bodied aircraft predominating.

Any airplane used as a medevac aircraft must offer certain features in order to provide an adequate level of care for the patients being transported. In summary, these features are:

Normal "People" Amenities

- Cooling and heating
- Pressurization
- Lavatories
- Galley
- Sound insulation
- Cabin lighting

Medical Needs

- 60-Hz, 115-vac power at each litter
- Therapeutic oxygen at each litter
- Emergency oxygen for patients and crew
- Medical storage area
- Medical crew seating
- Litter support system

The proposed use of the airplanes in the CRAF-LRI fleet for medical airlift has many positive aspects, most of them associated with an improved patient environment, better availability of aircraft as compared with the military fleet, and the enhancement of military airlift's ability to perform its mission. For CRAF to be used in this role, however, requires the development of a system to providing, aboard the planes, the minimum amenities and medical care systems necessary for maintaining the well-being of the patients being transported.

The existing system used with military transports cannot simply be transferred to civil transports "as is" because the working of the system depends upon a number of features available on the military planes (such as tiedowns and ceiling anchors) that are not found on the civilian planes. Due to the real-world economic and political elements involved, utilization of the CRAF planes must be accomplished in a way that least affects the owners' use of them--that is, not modifying the planes in any manner that would reduce their revenue-earning potential, and not doing any modification that would require a long layup of any airplane.

The best solution to this dilemma is to develop a medical care system that can be carried aboard a CRAF plane and, by using only the equipment found aboard, be set up and tied down as a completely integrated, fully operational airborne hospital ward. The proposed Modular Medevac System (MMS) recommended for adoption into the Air Force strategic airlift a network consisting of: (a) a Litter Support System; (b) a standard 210-liter liquid oxygen module with distribution hose systems; (c) a Unitron 400-to 60-Hz power converter with distribution cable systems; (d) comfort pallets for cargo aircraft; (e) a Transportable Airborne Therapeutic Station (TATS); (f) biological refrigerators; and (g) other medical equipment and materials.

Application of the modular medevac system to the aircraft in the CRAF-LRI fleet results in a certain capacity of patients per airplane type. If a ratio of patient types equal to 60 percent litter and 40 percent ambulatory is used in loading each plane, and space is set aside for the seating of medical crewmembers, and for the carriage of TATS units and other medical equipment, the number of patients who can be carried ranges from 54 in the B-707 to 179 in the B-747. Cost of the MMS is about one-tenth the cost of a program of aircraft modification to accomplish the same purpose. Thus, the MMS appears to offer significant advantages over any other program of major modification.

The "bottom line" concerning the utilization of CRAF for medical airlift, therefore, lies in three basic factors: (a) CRAF includes over 60 percent of the civil wide-body airline fleet, and this enormous airlift capacity should

ensure maximum availability of aircraft for medevac. (b) The passenger planes in CRAF offer a much better patient environment than that afforded by the craft in the C-5/C-141 fleet, and this factor could help alleviate morbidity of the airborne patients. (c) With a good modular medevac system, the planes in CRAF can quickly be configured for medical airlift missions and then be reconfigured to their original role just as quickly. Thus, the use of CRAF for medevac seems the wise course.

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Information concerning the composition of the CRAF was provided by Lieutenant Colonel Michael A. Harden of HQ MAC/XPW; data on aircraft interior configurations came from L. E. (Gene) Allen of Trans World Airlines, Inc. (Kansas City, MO), and John A. Sands of American Airlines; electrical data were supplied by Larry L. James of Trans World Airlines, Inc., and William R. Detamore of American Airlines; and most of the other technical facts, including many drawings and manuals, were furnished by William E. Singer of Douglas Aircraft Company (Long Beach, CA), A. W. Turner of Lockheed-California Company, and Mike T. Boyce of Boeing Military Airplane Company.

Several equipment companies were involved in this effort, including: Tescorp, Inc. (electrical cables); Weber Aircraft Company (seats); Clifton Precision Division of Litton Industries and Texas ROMEC, Inc. (oxygen systems); Browline Div/LAX and ANCRA Corporation (tiedown equipment); Unitron Inc. (electrical converters); and Southwestern Controls Corporation (vacuum system).

Finally, our especial thanks go to Brigadier General (Ret.) Claire M. Garrecht, for her invaluable comments and suggestions concerning the day-to-day issues of aeromedical nursing that she faced during the Vietnam era.

Richard E. Thomas
Principal Investigator

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THE USE OF THE CIVIL RESERVE AIR FLEET IN EVACUATION OF BATTLEFIELD CASUALTIES

An Evaluation

INTRODUCTION

Background of the Study

The aerial transport of battlefield casualties from a remote theater of operations to hospitals in the United States will, during a major wartime contingency, place a heavy burden upon an already over-burdened military airlift system. This prospect, coupled with the lack of a plan for alternative means of medical airevac, is a cause for concern on the part of those individuals and organizations responsible for the care of wartime wounded.

The present system of intertheater aeromedical evacuation (strategic medevac) primarily uses C-141s that have been temporarily reconfigured to accommodate both the seriously ill as litter patients and the less seriously ill (the ambulatory or "walking-wounded") as sitting patients who are transported upright in seats. This system, however, has numerous shortcomings. For example, the C-141 is not a people-oriented vehicle and lacks most of the amenities found in regular passenger-carrying aircraft. As a result, conditions aboard are not only barely tolerable for healthy people, but can be physically deleterious for the ill and wounded.

Other problems exist with the present system. Most of these arise from the fact that medevac is not a primary role for the strategic airlift fleet, and the medevac's needs do not adapt well to the requirements and mode of operation of the airlift's main mission. This problem is most evident in at least three major areas of concern:

First, the C-141 flow pattern (schedules and routes) is set up to maximize the use of the system's resources for force deployment, and all other uses of the fleet must fit into and around this activity without degrading it. One result of this pattern is that the routes and stops utilized in the force deployment mode typically do not include cities where major medical centers are located, thus complicating the movement of patients to suitable CONUS [refer to "Abbreviations and Acronyms"] facilities.

Another obstacle to medevac use in airlift operations is the requirement for fast turnaround (minimum ground time) at each stop. However, the amount of time required for reconfiguration of an aircraft and for enplaning and/or deplaning of patients conflicts with this desired criterion and compromises

EDITOR'S NOTE: For the convenience of the reader, the "Abbreviations and Acronyms" used herein have been listed and defined on the final page of this report.

the effectiveness of the airlift fleet in performing its primary mission. Consequently, the medevac crews can find themselves under pressure to conform to the force deployment schedule, and therefore might be pushed into a situation where the quality of care would suffer.

The third area of concern involves the reduction in payload capability that results from the required backhaul, from CONUS to a foreign theater base, of the special equipment (seats, litters, oxygen systems, etc.) used in medevac. The estimated lost capacity amounts to 10 percent or more of the usable payload (46). This figure, although seemingly small in a peacetime perspective, could be significant in a wartime contingency.

To bring some relief to the situation, the suggestion has been made that aircraft belonging to the Civil Reserve Air Fleet (CRAF) could be used in the medevac role. To date, however, little has been done about developing such a plan; thus, a need exists to explore and carry this idea forward to the point where medevac planners and commanders can make the necessary "go/no-go" decisions concerning implementation of a suitable plan.

The potential for utilization of the CRAF for medevac is excellent, due to the size and composition of the fleet. In terms of size, the passenger-carrying capability of CRAF has been estimated to far exceed the projected troop deployment requirements of a wartime contingency (21). With 323 airplanes in the long-range international (LRI) part of CRAF, all of the wartime troop deployment and medevac demands could be met and, simultaneously, the ability of the strategic airlift system to handle large and oversized cargo would be increased.

In terms of composition, the LRI fleet consists of 707, DC-8, 747, DC-10, and L-1011 types, with the wide-bodies predominating. The utilization of these aircraft for medevac would not only ease the expected wartime burden on the airlift system, but would also provide a better quality of patient care than presently exists using the C-141 system. For example, the use of civil aircraft, both wide- and narrow-bodied, would: (a) result in a more tolerable patient environment; (b) provide a point-to-point flow system for patient movement; (c) operate outside of the congested military airlift system; (d) be able to perform the medevac mission using fewer aircraft, thus simplifying the scheduling and control problems; and (e) operate on a schedule designed to meet the needs of medevac instead of the reverse.

In addition to the other advantages, the use of CRAF for the intertheater movement of wounded would simplify the scheduling and utilization of the C-9A fleet. Because of the possibility for point-to-point moves directly from the theater recovery bases to the Civilian-Military Contingency Hospital System (CMCHS) sites, the requirement for transshipment by C-9A would be reduced to a minimum. Thus the C-9A fleet would be available for specialized intratheater moves, and the C-9A utilization rates would be significantly improved.

Purpose and Objectives of Study

Simply stated, the purpose of this study has been to determine how the aircraft of the CRAF could best be used for strategic aeromedical evacuation (medevac). Conceptualizing a system and plan to accomplish this goal, however, has not been quite as simple. The whole question of using the CRAF aircraft for such a purpose involves a number of considerations related to their adaptability to the mission. One must also consider whether the plan for use of these planes is practical, in light of the real-world constraints on availability for modification as well as availability for medevac missions after Stage III activation.*

As for the issue of adaptability, a system should be designed for reconfiguration, including the necessary permanent modifications to an aircraft, that will meet the needs of medevac in a cost-effective manner. This plan is fairly straightforward and uncomplicated, requiring only that the design be one that not only does a job that is adequate, but also at minimum cost and with minimum change (or damage) to the aircraft.

The first part of the availability issue--availability of an individual airplane for advance modification work--can be resolved most easily by ensuring that the proposed reconfiguration approach minimizes the amount of permanent modification required. The factors of cost and added weight are very important, but these can be resolved by compensating the airlines for the cost of modification and lost payload. A factor that is not so easily resolved (one that has been impeding the CRAF enhancement program to strengthen the floors of a number of jumbo jets) hinges on the length of time that an airplane must be out of service while modifications are being made. Since deregulation, market share has become a critical factor in the survival of airlines; and, in some cases, withdrawing a single airplane from service for an extended period can prove disastrous to an airline's financial stability.

The second part of the availability issue--availability of the CRAF planes for medevac, due to the many conflicting demands that will exist at the time of a Stage III callup--cannot be predicted with any degree of certainty because of the uncertainty of the nature of a wartime scenario. During a major armed conflict, however, the evacuation of wounded from a foreign theater of operations to CONUS will doubtless be given priority over most civilian travel. If so, the availability of CRAF aircraft for medevac should not be a problem.

To achieve the purpose of this study, as just described, the five major objectives are:

- a. To design a reconfiguration system that adequately provides for the needs of intertheater medevac using CRAF

* NOTE: Stage III Activation. A call-up of all of the planes in the CRAF inventory. Will require the President or Congress to declare that a national emergency exists.

- b. To specify components, for the system, that will result in minimum system cost
- c. To combine system elements in such a way as to require a minimum amount of advance modification to each individual airplane
- d. To estimate costs
- e. To recommend a call-up priority for the aircraft in CRAF, on the basis of the type of airplane and its size, as well as the results of the foregoing objectives

Significance of the Study

The results of this study, along with the findings of the recommended follow-on studies will, when implemented, constitute a system for strategic aeromedical evacuation that will be considerably superior to the present system which utilizes the military airlift fleet. The new system will not only provide for better handling of patients than is possible with the present system, but will also free the strategic airlift fleet to do an even better job of heavy equipment movement.

At the present time, no comprehensive plan exists for the use of CRAF for medevac. However, the program described and recommended in this report, if implemented, makes such use possible and in a very practical manner. Additionally, the modular kit that constitutes the nucleus of the CRAF utilization plan recommended herein can also be used to provide better patient handling in most military transport aircraft, including those of the Air Force, Army, and Navy.

Assumptions

The major assumptions upon which this study was conducted are as follows:

- a. The typical medevac patient load will consist of, by number of patients, 60-percent litter patients and 40-percent ambulatory patients.
- b. Ten percent of the litter patients will require respirators, and Bird Mark-10 units will be used.
- c. For one-half of the flight, the medevac plane will be unable to maintain cabin pressure, and emergency oxygen will be needed for this period.
- d. Required oxygen pressures and flow rates will be:
 - 50 \pm 5 psig pressure
 - 2.2 liters per minute (lpm) flow for emergency use

6.0 lpm for therapeutic use

15.0 lpm flow for respirator use.

- e. The electrical requirements will consist of 1 amp of 60-Hz/115-vac power for each litter patient.
- f. To energize the electrical conversion system, 400 Hz/115 vac power will be available in the main cabin of each CRAF aircraft.
- g. No more than three litters will be carried in each vertical tier.
- h. A liquid oxygen source will be available at one stop of each medevac flight.

Limitations

The findings of this study are subject to the following limitations:

- a. CRAF aircraft will be available for medevac upon Stage III callup.
- b. The validity of the study findings is limited to the accuracy of the data found in various official Air Force publications made available to the researchers, including: AFP 164-2 (ref. 36); MACR 55-8 (ref.39); and MACP 55-41 (ref. 11); along with DN5A2 and DN6A1 of AFSC DH 2-2 (refs.18-19); and copies of other reports and correspondence.
- c. The various responses received during interviews--with representatives of MAC, USAFSAM, the airlines, the aircraft manufacturers, and all equipment suppliers--were reasonably accurate.

REVIEW OF SELECTED LITERATURE

The identification and the review of literature pertinent to this study were undertaken, with inquiries being made through two major bibliographic retrieval services. One of these services was directed at the nonmilitary medical journal field--the other, at the data banks of two sources of Government-funded research reports: the National Technical Information Service (NTIS), and the Transportation Research Information Service (TRIS).

The first inquiry utilized a system available at the Texas A&M University Medical Sciences Library, the Bibliographic Retrieval Service (BRS). Using this system, entry was made into the Medline data base, a well-known, nationally available medical literature file. Shown in Table 1 are the keyword sequence that was followed and the results of each step.

TABLE 1. RESULTS OF MEDLINE DATA BASE SEARCH

Key words	Number of entries
Aircraft	309
Evacuation, ambulance, mercy	1,165
Aircraft ambulances	25
Emergency medical services	1,439
Aircraft and emergency medical services	56

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

A second inquiry was made using facilities of the main university library at Texas A&M. This search, through the DIALOG system, looked at both the NTIS and the TRIS data banks. The keywords used and the number of entries fed back are shown in Tables 2 and 3.

TABLE 2. RESULTS OF NTIS DATA BASE SEARCH

Key words	Number of entries
Aeromedical	29
Evacuate, evacuation	50
Casualty, patient	43
Wounded	15
Medical, emergency, mercy	42
Aerospace medicine, surgeon	13
Litters	1
Civil Reserve Air Fleet	11

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

From these searches, a total of 73 articles and reports having potential application to the study were identified and obtained. In addition, reports, manuals, and databooks were acquired from airlines, aircraft manufacturers, and the sponsor. Out of this overall collection, however, only 56 items were found to have any significant application to the study; and these have been listed in the "Selected Bibliography" section of the report.

TABLE 3. RESULTS OF TRIS DATA BASE SEARCH

Key words	Number of entries
CRAF, Civil Reserve Air Fleet	3
Emergency, medical, health	8
Patient, casualty	14
Evacuation	14

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

Historical Background of Medical Airlift

The first large-scale use of aerial transportation for ill and wounded patients did not occur until World War II (WW II). However, the practice existed as early as 1870, when soldiers who had been wounded in the siege of Paris were airlifted out by balloon (24). During more modern times, medical airlift using airplanes was practiced on a small scale during the First World War (36).

Until very recently, the use of medical airlift has been restricted almost entirely to military patients, principally under wartime conditions. Thus the advanced technology, which today permits the widespread use of airplanes and helicopters for the movement of gravely ill persons in a peacetime civilian environment, is mainly the result of extensive military experience gained during WW II, and in Korea and Vietnam.

Early attempts to use the airplane for movement of the ill and injured were regarded as unsafe and impractical. As aircraft performance and reliability improved, however, the concept of using airplanes as ambulances gradually became a more feasible option (36).

In 1943, medical airlift took a giant step forward when the Army Air Corps rapidly moved ahead to implement the technique, developing the idea of multipurpose quick change transports as an integral part of the system. As a result, more than one million patients were moved by air during WW II (36).

By 1949, the official policy of the Defense Department was that all long-distance moves of military patients were to be by airlift. The only exceptions to this practice would be those dictated by medical constraints (36).

Widespread use of helicopters in Korea and Vietnam extended the concept of medevac, as it was now known, into a nearly universal system. From the actual site of the injury to a major hospital, military personnel (and sometimes civilians) were being moved by aerial means almost exclusively. As a result, the mortality rate for wounded reaching medical treatment facilities declined from 4 percent in WW II to 2 percent in Korea, and then to 1 percent in Vietnam (36).

Medical Airlift Today

Today, the aerial transport of wounded has become a widespread and routine practice, in both the civilian and the military environments. In most situations, the distance to a specialized treatment center is the main justification for using air transportation.

In those cases of trauma brought on by severe injury from an accident or as a result of hostile, wartime incidents, the helicopter is typically the first mode of movement for the patient (4, 20, 43). Depending upon the availability of equipment, however, the movement could be by helicopter or fixed-wing aircraft (26, 27, 54). After patients have received emergency treatment and are somewhat stabilized, if the injury or illness is serious

enough to call for prolonged or specialized treatment at a distant medical center, fixed-wing airplanes become the primary means for this movement (2, 28, 56).

Physiological Aspects of Medical Airlift

Almost any patient may be carried by air, but air transport introduces some special problems due to the effects of altitude, noise, turbulence, and the special environment. Because of these factors, one must know, when considering a patient's suitability for air transport, the type of aircraft to be used, the flight profile—its duration and expected cabin altitudes—and the facilities available on board. It is essential to carry all equipment (as simple and as portable as possible), drugs, and diets that may be needed, and to be sure that all the skills and nursing help needed to deal with any possible problems are available (40).

Although noise, turbulence, air dryness, and cabin temperatures are important factors to consider during the aerial movement of patients, the effects of altitude seem to create the most serious problems. Changes in altitude can have disastrous effects because diminished ambient air pressure may allow gases in closed spaces and tissues to expand rapidly. Hypoxia, for example, is a condition that is aggravated by altitude changes (44).

The problem is difficult to contain or eliminate because even pressurized commercial aircraft do not maintain sea-level pressure: cabin pressures equal to those at up to 8000 ft. may be experienced, thus diminishing oxygen tension in proportion. Air transport is absolutely contraindicated for patients with untreated pneumothorax, gas gangrene, or air trapped in the cranium, and those who have recently undergone abdominal surgery. Special considerations—including a planned low-altitude flight—are warranted for patients who are anemic, in respiratory or cardiac distress, or immobilized in casts, or who have been engaged in underwater diving immediately before the flight (41).

Because of concern with the complications of aerial movement, aeromedical evacuation personnel have learned to classify patients and to control the airlift process carefully in order to minimize problems. On the basis of the makeup of a patient load, planes are required to follow a specific flight profile in terms of maximum altitude, number of stops, length of legs, and other factors.

The load plan, for example, requires that patients be placed aboard the airplane according to their classification (psychiatric, nonpsychiatric, litter, ambulatory), severity of illness, and need for observation and personal comfort. Patients with heavy casts or those who require the most medical care go in lower litters, which are easiest for the flight nurse to reach. Litter stations on forward sides of the aircraft are preferred for the very ill. Patients with spica casts need two litter positions. Stryker frames require three (24).

Experience has proven that any patient capable of being moved can be moved by air. Although patients must be carefully selected and fully preflight prepared, medical airlift has played a key role in improving the survival rate of the wounded (24). Medevac, thus, continues to be a viable part of the overall care and treatment regimen for ill and wounded military personnel.

RESEARCH PROCEDURE

The research described in this report was a comparative descriptive analysis conducted during the summer of 1983. The study was designed to examine the system of aeromedical evacuation operated by the United States Air Force, and to attempt to conceptualize a plan for utilizing the airplanes of the Civil Reserve Air Fleet in this role. The data on which the findings are based were obtained through interpersonal interviews and telephone interviews, and from published secondary sources.

Interpersonal and telephone interviews were conducted with the following people and organizations. Air Force personnel were contacted at: Scott AFB, Illinois; Brooks AFB, Texas; Travis AFB, California; and the Pentagon, Washington, D.C. Also, airline personnel with American Airlines, Trans World Airlines, United Airlines, Arrow Airways, Capitol Air, and Transamerica Airlines were interviewed as were persons at Lockheed-California, Boeing, and Douglas Aircraft Company to obtain technical data concerning electrical systems, floor load limits, cabin layouts, and other details of the CRAF airplanes that could be pertinent to our research.

To obtain technical details of ancillary equipment that might be used as part of a medevac modular system that could be carried aboard a CRAF airplane, contact was made with: Tescorp (electrical cables); Unitron (electric power converters); Clifton Precision (oxygen systems); ROMEK (oxygen systems); Aeroquip Corporation (oxygen hoses); Brownline (equipment tiedown systems); and Weber Aircraft (seats). Finally, to explore the issue of emergency exit access, discussions were held with the Federal Aviation Administration (FAA) operations center in Houston, and the FAA regional council's office in Fort Worth.

The published secondary sources that were consulted included both civilian and military publications. The major ones are given in the "Selected Bibliography" section of this report.

To ensure that the study was comprehensive in covering all of the essential points necessary to make a decision on the practicality of using CRAF for medevac, an orderly procedure was followed. The steps in this approach were:

- a. Review the literature on medical airlift.
- b. Review the present equipment/procedures used for medevac by the Air Force.
- c. Identify the basic needs of medevac.
- d. Evaluate the CRAF assets.
- e. Assess the capabilities of CRAF for use in medevac.

- f. Conceptualize equipment designs and costs associated with using CRAF for medevac.
- g. On the basis of capabilities, costs, and suitability for medevac, make a rank ordering of the CRAF aircraft for Stage III call-up.

The results of Step 1 (review of literature) have been described in an earlier section. Treatment of the other steps is presented in the following report sections.

EXISTING SYSTEMS AND RESOURCES

Current U.S. Air Force System

The Air Force aeromedical evacuation (medevac) system is divided into three subsystems. These provide the tie-in between the final destination medical facility and the forward airlift phase at the battlefield. The following excerpts from Mazulewicz (36) and Funsch et al. (24), as paraphrased and combined here, give a good description of the Air Force system:

Intratheater Aeromedical Airlift. The intratheater aeromedical airlift phase provides transport for all US Forces from point-to-point within an overseas theater of operations. This phase interfaces with both the forward phase and the intertheater phase. It is under the jurisdiction of the Military Airlift Command (MAC) 375th Aeromedical Airlift Wing (AAW), Scott AFB, IL. In peacetime, the primary aircraft is the C-9A "Nightingale" with the C-130 "Hercules" as its backup.

(1) Pacific Air Forces (PACAF). All patient movements within the Pacific Theater (Japan, Korea, the Philippines, etc.) are the responsibility of the 9th Aeromedical Evacuation Squadron, located at Clark AB in the Philippines.

(2) United States Air Forces in Europe (USAFE). All patient movements within the European Theater (Germany, England, Spain, Turkey, Italy, Greece, etc.) are the responsibility of the 2nd Aeromedical Evacuation Squadron, Rhein-Main AB, Germany.

Intertheater Aeromedical Airlift. The intertheater system provides airlift for patients from overseas theaters back to aerial ports in the CONUS. It interfaces with both the intratheater and domestic systems and is under the jurisdiction of the 375th AAW. All intertheater flights are by jet transport. MAC's long-range transport, the C-141 Starlifter, has space for 80 litters in rows of three and four tiers each. The swept-wing jet has a nonstop range of 5,250 miles and flies at speeds up to 550 mph. Most intertheater flights terminate at MAC's aerial ports on the east and west coast or at Andrews Air Force Base near Washington, DC. (Aircraft with serious burn cases on board may be extended to the military burn center in San Antonio, Texas.)

Domestic Aeromedical Airlift. At aerial ports in the United States, patients become the responsibility of the third subsystem. The 57th Aeromedical Evacuation Squadron, Scott AFB, Illinois, provides the domestic

airlift system for patients within CONUS and from nearby offshore points in the North Atlantic and Caribbean area. This system's primary aircraft is the C-9A "Nightingale." MAC's domestic system has three types of scheduled flights--"trunk" and "feeder" lines are operated by seven aeromedical units located at several strategic points in CONUS.

Nonstop trunk line aircraft fly regularly between the seven aeromedical units. The jobs of feeder flights is to pick up or drop off patients at military hospitals within each of the seven areas.

Off shore missions serve military bases in Alaska, Newfoundland, Labrador, Bermuda, Puerto Rico, the Canal Zone, and Guantanamo Bay, Cuba.

The airplanes typically used by the Air Force for medevac are the C-9, the C-130, and the C-141. Each features certain advantages for medical airlift; however, only the C-9 could be considered a truly complete medevac airplane. The following excerpts from Mazulewicz (36) give the highlights of each airplane:

C-9 Nightingale. The C-9 is a military version of the DC-9 commercial aircraft. The T-tailed aircraft is powered by twin, aft-mounted jet engines, and cruises at 500 mph with a range in excess of 2,300 miles. Equipped with an auxiliary power unit (APU), the C-9 can generate its own electrical power and pneumatic pressure without support from ground units. With the APU operating, the climate control system maintains an even temperature. An integral folding ramp enables efficient enplaning and deplaning of litter patients. Ambulatory patients can be enplaned or deplaned at the same time through an aft stairway, thus reducing ground time. The modern features of C-9 include a special care area, medical service area, central stowage area, medical crew stations, and communication and call systems. The interior configuration is easily converted to accommodate various combinations of litter and ambulatory patients. The basic interior configurations of the aircraft using three litters per tier are:

- (1) Twelve litter, 28 seats in the mixed configuration.
- (2) Forty ambulatory seats with three litter in the special care area.
- (3) Thirty litters.

All litter tiers incorporate provisions to carry four litters, permitting a maximum of 40 patients in the full litter configuration. Under normal conditions, the four-deep configuration is limited to one or two enroute stops.

Litter support equipment consists of a folding support stanchion, a utility stanchion, and cantilever support arms. All are easily inserted, adjusted, or removed from the stanchion tracks. The utility

stanchion contains a patient console, providing each patient with a nurse call system, reading light, speaker, cold air regulator, emergency oxygen mask, and ashtray. When used for ambulatory patients, the utility stanchion is stowed horizontally above the seats.

Two independent liquid oxygen (LOX) systems are installed in the aircraft. One provides oxygen to crewmembers in the flight compartment. The other provides oxygen to emergency oxygen mask, therapeutic oxygen outlets, and recharger outlets.

The vacuum system installed in the aircraft provides a source of suction for therapeutic use. The system is capable of ground and inflight operation and includes a vacuum pump, a distribution system, inlets, and assembly units (gauge, regulator, and collection reservoir).

The aircraft is equipped with both an AC and DC electric power system. The AC system is 115 V, 60 Hz and has two outlets at each litter position, as well as four in the special care area. The DC system has one 28-V outlet in the special care area.

C-141 Starlifter. The C-141 is a long range, high speed, high altitude, swept wing aircraft, designed for use as a heavy logistics transport. It is powered by four jet engines and cruises at a speed of approximately 550 mph with a range of 5,250 miles. Unlike the C-9, the C-141 is a multipurpose aircraft. It can be configured to carry troops, cargo, or patients. When used for aeromedical airlift, a self-contained comfort pallet is placed in the forward section of the cargo compartment. It consists of two latrines and a galley area, and also contains its own water supply. The C-141 has an auxiliary power unit (APU) located in the left wheel well, which provides electrical and pneumatic power while the aircraft is on the ground. At present, because of its long range capability it is the only aircraft used in intertheater aeromedical airlift. The C-141A can carry 79 litter patients or 102 ambulatory patients with a comfort pallet in place. The "stretch" C-141 will carry 103 litter patients or 147 ambulatory patients with a comfort pallet in place. In all configurations nine crew seats are reserved. The aircraft can be configured to meet various litter and ambulatory requirements.

Litter support provisions are carried and stowed aboard the C-141 to configure it for aeromedical airlift. In an emergency, however, when the aircraft is used in a "surge" mode, the normal equipment carried aboard the C-141B will allow it to carry only 32 litter patients or 70 ambulatory patients.

The C-141 is equipped with two completely independent LOX systems, one for the flight crew and one for personnel in the cargo compartment. Both

operate at a pressure of 300 psi. The crew oxygen system consists of a 25-liter LOX converter located in the nose wheel well. It supplies oxygen to crew members in the flight compartment and to five recharger outlets: two in the flight compartment and three in the cargo compartment. The troop oxygen system consists of two 75-liter converters located in right wheel well. This system provides oxygen to ambulatory and litter patients, in the event of an emergency, via canister masks which are located throughout the cabin. A continuous flow system, it automatically provides oxygen in the event of cabin depressurization. In the cabin of the aircraft there is a troop oxygen panel which allows a crewmember to perform an operational preflight check. There are seven oxygen outlets for therapeutic use. Three are located in the panel on the right bulkhead in the forward section, and four are located in the panel on the right bulkhead in the midsection.

The aircraft is equipped with two electrical systems, AC and DC. The AC system provides both 115/200 V, 400 Hz and 115 V, 60 Hz outlets in the crew and troop latrines. The DC system provides two 24-28 V outlets in the cargo compartments.

C-130 Hercules. The C-130 is a long range, high-wing four turboprop engine aircraft. The fuselage is divided into the cargo compartment and the flight deck. It can be fully pressurized, heated, and airconditioned. The C-130 can land and takeoff on short runways and be used on landing strips such as those usually found in forward operating areas. The mission of the aircraft is to provide a rapid transportation of personnel and cargo. It can be readily converted for aeromedical airlift by using seat and litter provisions stowed in the cargo compartment. The galley contains a water supply, ovens, food warming cups, and food storage compartments. In the maximum litter configurations of five litters per tier, the C-130 has space for 74 patients with two seats for crewmembers, or space for 70 litter patients with six seats for crewmembers. In the all-ambulatory configuration, there are seats for 92 ambulatory patients. Also, mixed configurations are possible, such as 40 litter and 20 ambulatory.

Litter support provisions are similar to C-141 provisions and include litter stanchion poles with removable litter support brackets and suspension straws with adjustable litter support brackets. Potential litter tiers are located on both sides of the aircraft and double litter rows down the center cabin. A rear loading ramp and auxiliary ramp extensions are used for enplaning equipment and patients.

There are two types of crew oxygen systems. Early versions of C-130 aircraft are equipped with a high pressure gaseous system, while later versions are equipped with a 25 liter LOX converter. Both systems supply oxygen to crewmembers in the flight compartment and oxygen for the recharger outlets. Therapeutic oxygen is not available as part of the aircraft system. It is brought aboard by the medical crewmembers and may consist of a portable LOX unit, high pressure oxygen cylinder, therapeutic oxygen kit, or a combination of all three.

The aircraft is equipped with two electrical systems. The DC system has several 24-28 V outlets located in the cargo compartment, while the AC system provides a number of 115/200-V, 400-Hz outlets in the same area.

Other elements of the Air Force medevac system include hospitals, aeromedical staging facilities (ASF), medical regulating agencies, and the main control point of the system--the Aeromedical Evacuation Control Center (AECC) (24):

A telephone "hot line" connects central ACEE with subordinate control centers in each of the seven aeromedical areas. A unique dial system permits conference calls between any or all units. Use of the "hot line" keeps central AECC up to date on the number of patients to be moved and how many aircraft are available to move them. In addition, progress of each en route patient is pinpointed on a status board in the command control room.

The existing system is one that has been successful in the past, and offers a number of advantages when compared with the CRAF. The most significant positive features of the C-9, C-130, C-141 fleet are that: (a) the aircraft are already on the scene in most parts of the world, and would be available almost immediately for medical airlift; (b) both of the nonmedical aircraft, the C-130 and C-141, are basically freighters--and no equipment would have to be removed before preparing them for medevac, thus making reconfiguration a faster process; (c) because these are military aircraft and are designed for operations near a front, they can be used to airlift sick and wounded back to CONUS with fewer intermediate equipment changes.

Being military airplanes and being designed to move military cargo, however, means that the Air Force transports also suffer from several disadvantages as compared with CRAF airplanes when used for medevac:

1. Their onboard environment is not conducive to being used for airlifting the sick and wounded.

2. The routes and schedules of the Military Airlift Command (MAC) do not correspond to the needs of medevac.
3. The MAC philosophy of "fast turnaround" complicates patient loading and unloading.
4. MAC aerial ports and cargo unload points lack congruence with the locations of major medical facilities and the civilian-military contingency hospital system (CMCHS).
5. The strategies for fighting and winning wars cannot place as much emphasis upon the handling of casualties as they do upon the logistics of weapons and troops; thus, medevac has a fairly low priority in the total picture of air transportation in wartime.

Basic Needs of Medevac

Aeromedical airlift has certain basic needs that must be supplied if the patients on a medevac flight are to receive adequate care. When these needs are properly met, the equipment and the level of onboard care approximates what might be found in an earthbound hospital ward; therefore, an adequately equipped medevac aircraft might well be dubbed an "airborne ward."

To be considered as a candidate for the role of airborne ward, an airplane must be one that is equipped to furnish the essentials of human creature comfort. Lights, heat, air-conditioning, ventilation, lavatories, and pressurization must all be available in the cabin to qualify an airplane for consideration as a medevac craft. Such amenities are found on all passenger (PAX) airplanes, and even on some cargo planes.

Beyond creature comforts, a true airborne ward must also provide a number of highly specialized features peculiar to its mission. Some of these are: a therapeutic oxygen system; a 60-Hz, 115-V AC electric power system; seating for ambulatory patients; some type of accommodation for litter patients; seating for the medical crew; and storage for plasma, drugs, dressings, and other direct-care items (suction pumps, I.V. supplies, etc.). Most of this material and equipment can be carried aboard the plane and set up for a medevac flight. This procedure is used throughout the present AF medical airlift system, except in the case of the C-9 Nightingale aircraft.

To meet the needs of the present system, especially designed equipment (such as portable electric power converters and lightweight respirators) has been developed. However, much of this equipment has a somewhat limited capacity; some of the equipment is the same as that used by forward medical units, and much of it is marginal in performance. No matter how suitable for the present system, therefore, some of the present portable equipment must be upgraded, or new equipment built, if the airplanes in CRAF--especially the wide-bodied type--are to be effectively utilized in a medevac role.

In affording the best care to patients, if the CRAF is to be used for medical airlift, the first step is to define the basic parameters of need for these persons. The major needs are:

Oxygen. The oxygen requirements aboard an airborne ward (aside from crew needs) include the use of therapeutic masks to treat various oxygen-deficient conditions, the use of respirators for those patients with breathing difficulties, and a supply of emergency oxygen for patients and medical crew during periods of cabin pressurization loss. For therapeutic masks, a system is required that will supply 6 lpm of 100-percent oxygen at a pressure of 50 ± 5 psig to each litter position. Respirators, assumed to be required for about 10 percent of the litter patients (1), should be supplied with 15 lpm of 100-percent oxygen from the system. For emergency use during periods of pressurization loss, the system must be able to supply 2.2 lpm of 100-percent oxygen at each litter and seat (1). Finally, the system should provide a capability for recharging at 300 psig the walkaround bottles used by the medical crew.

Electric Power. Most electrically powered medical equipment is designed to use normal household electricity, that is, 115- to 120-V, 60-Hz alternating current (AC). Historically, a typical medevac patient mix has an electrical requirement of 1 ampere of 60-Hz, 115/120-V AC power for each litter position (47).

Heating, Ventilation, Air-Conditioning (HVAC). The HVAC system should be able to maintain a temperature of 70° F at the floor, with an air velocity of 25 - 50 ft/min, and a uniform distribution of the air vertically so that the temperature fluctuates no more than 5° F between the lowest and highest litter positions (1).

Toilet Facilities. Every airplane should have at least two recirculating, flush-type latrines, each with a 20-gal capacity holding tank. For loads greater than 60 people, at least one latrine should be included for each additional 30 persons. With each latrine should be available: one urinal; one wash basin with hot and cold water; and storage for air sickness bags, toilet paper, sanitary napkins, and paper towels (1).

Litter Spaces. For each medevac flight, equipment should be included for supporting and tying-down standard NATO litters in a configuration that allows bilateral access to each litter, as well as access at each end of a litter for mounting various types of medical equipment. Additionally, each litter should have a minimum 18 in. of vertical separation above each litter, and each end of the litter should be adjustable up and down in 1-in. increments. Also, no litter should be placed higher than is conveniently accessible by a flight nurse or aeromedical evacuation technician, nor should any litter be located lower than 5 in. above the floor (1).

Life Vests and Rafts. All medevac aircraft should be equipped with enough life vests to accommodate all of the passengers—patients, medical crew, and aircraft crew. Special life vests for each of the litter patients should also be included. In addition, the aircraft should have a sufficient number of rafts aboard to accommodate the entire load, based upon placing 14 people into each 20-man raft, thus allowing space for medical supplies (1).

Tiedown Capability. Each aircraft for medevac should have facilities and equipment for tying down all carry-aboard equipment. These tiedown facilities can consist of seat tracks, D-rings, bulkhead attachment points, or other means of adequately securing equipment that may be carried aboard.

Litter and Stryker Frame Access. All aircraft assigned to medevac missions must have doorways, ramps, or other types of access openings that are large enough to permit the enplaning and/or deplaning of both litters and Stryker frames. Aisleways and interior obstructions shall also be taken into consideration in analyzing the degree of access afforded.

Food and Water. Provision must be made for the storage and preparation of food, and the storage and dispensing of water (and other liquids) to patients and crewmembers. The size of patient load and the duration of the flight will dictate the amount of water, as well as the amount and type of food carried aboard. Storage shall be designed to hold water at a temperature not to exceed 70° F, and for food to be refrigerated, including a proportional amount of freezer space (1).

Medical Storage. Approximately 150 ft³ of storage space should be available for routine and special carry-on medical equipment. The Transportable Airborne Therapeutic Station (TATS) will require approximately 42 ft³, while the remainder of the space would be needed for biological refrigerator and other miscellaneous items, including several spare litters. Space allocated for these materials should be situated so that they are not a hindrance to movement about the cabin by patients and crew (1).

In addition to meeting the basic needs for medevac, another need would be to provide a location for the medical crew director to be seated and have access to a 24-in. X 48-in. writing surface. The position should also have storage facilities for patient records, including X-ray data, and other necessary manuals, books, and writing materials.

Composition of CRAF

To carry forward the planning associated with the proposal to make use of the long-range international (LRI) part of CRAF for intertheater medical airlift during a wartime contingency, information must be available on: the composition of the fleet in terms of airplane types, numbers, and size; and also certain technical data concerning dimensions, configurations, operating systems, and load capacities. Portions of these data exist in several places; e.g., airlines, airplane manufacturers, and the CRAF office of Headquarters, Military Airlift Command. For this study, a number of these sources were consulted to obtain the data used in the following analyses.

Listed in Table 4 is the basic composition of the LRI part of the CRAF—that is, the number of airplanes in the fleet by make, model, and configuration (passenger or cargo). Other, more detailed information (such as technical data) will be brought out in later discussions related to the factors affecting utilization of the fleet.

Two types of airplanes, in terms of configuration, make up the LRI fleet. As of 1 October 1983, this group comprised 214 passenger (PAX) types and 109 cargo types (Table 4). The composition of the LRI group, in terms of make and size, included the newer wide-bodied jets (B-747, DC-10, L-1011) as well as the older narrow-bodied ones (B-707, DC-8). In the wide-body category, CRAF has a total of 252 airplanes—204 PAX and 48 cargo in LRI. On the other hand, the U.S. civil airline fleet has only about 412 wide-bodied jets, thus giving CRAF about 60 percent of the total.

TABLE 4. LONG-RANGE INTERNATIONAL AIRCRAFT
IN THE CIVIL RESERVE AIR FLEET

Configuration	Type of airplane	Number
Passenger	B747/B747SP	111
	DC-8	10
	DC-10	66
	L-1011	27
	Total Passengers	<u>214</u>
Cargo	B707-300F/300C	13
	B747-100F/200F	30
	B747-200C	6
	DC-8-33F/50F/50CF	8
	DC-8-61CF	8
	DC-8-63CF/73CF	32
	DC-10-10CF	1
	DC-10-30CF	<u>11</u>
	Total Cargo	109
	Grand Total	<u>323</u>

SOURCE: Monthly CRAF Capability Summary--1 October 1983, HQ MAC/XPW,
Military Airlift Command, Scott AFB, Illinois

Capabilities of CRAF for Medevac

The capabilities of the CRAF resource for medevac can be measured in a number of different ways. The most obvious one, of course, is the sheer payload capacity of the LRI fleet as well as that of the individual airplanes in the fleet. With 323 large and jumbo-size aircraft available, CRAF-LRI has a passenger airlift capacity that is much greater than the projected troop deployment requirements of wartime contingency (21). For example, using only the ninety-nine B-747 PAX types in the LRI fleet, 36,000 troops could be moved to an overseas theater in one trip.

Another basis for measurement is the ease with which a CRAF airplane can be reconfigured for medevac. To evaluate this potential requires consideration of four factors: (a) the configuration of the airplane when received at the theater recovery base; (b) the advance modification concerning the plane; (c) the "people amenities" already aboard the airplane; and (d) the ease with which the modular medevac equipment can be installed and made ready. Behind this fourth factor (d), of course, are the issues of stowability, ruggedness, minimum number of parts and subassemblies, weight, and "fool-proofness." If a modular kit contains easily misplaced parts, is broken

or damaged in normal handling, occupies an inordinate amount of storage space, or is too heavy for ease of handling, then a good design in terms of operating parameters is not of much value in the total picture of utilization.

Finally, the availability of the CRAF-LRI for medical airlift might be considered the most meaningful measure of its capabilities. The strategic, long-range airlift capacity of the C-141/C-5 fleet is expected to fall far short of the requirements of a major wartime contingency. For example, according to a report in Army (32), one round trip by the entire C-5A fleet plus four trips by the C-141B fleet would be necessary to transport the 82nd Airborne Division—a unit that has been designed for air transportability. To move a "Division 86" mechanized division would require more than 5 round trips by the C-141 fleet, plus 11 such trips by the entire fleet of C-5As (32). In many instances, because of the inadequate airlift capability, airlift planners would have to delay the movement of troops to allow their heavy equipment to be deployed to the foreign theater first.

The limited airlift resource disclosed by these examples means that imposing the additional burden of medevac upon the system, even though the movement of patients would be counterflow to force deployment, could cause serious complications. Conversely, employing CRAF-LRI for the medevac and troop movement missions could act as a relief valve for the overburdened military system.

The utilization of the CRAF-LRI fleet for medevac offers several major advantages over the strategic airlift system. (These have just been discussed.) In addition, various components of the LRI fleet would offer advantages over other parts of the fleet in medevac application. For example, even though all of the medical "utilities," equipment, and supplies would have to be placed aboard any airplane used for medevac, passenger-configured aircraft would already have all of the "people amenities" described earlier; and these craft could be used, with no modification to the cabin interior, for the movement of ambulatory patients. To reconfigure these planes for the transport of litter patients would, however, require removal of many of the seats before litter support equipment could be installed.

On the other hand, cargo-configured aircraft could be used for the movement of any type of patient load without the necessity of stripping out existing equipment. However, cargo planes lack the amenities required for on-board patient accommodation and, even with the use of carry-on equipment, would offer little or no advantage over military transports in terms of the level of patient care. Summarized in Table 5 are some of the major differences between PAX and cargo aircraft in medevac applications.

The "bottom line" concerning the capability of CRAF for medical airlift, therefore, involves several basic factors: (a) CRAF includes over 60 percent of the civil wide-body airline fleet, and this enormous airlift capacity should ensure maximum availability of aircraft for medevac; (b) the passenger planes in CRAF offer a much better patient environment than that provided by the craft in the C-5, C-141 fleet, and this factor could help alleviate morbidity of the airborne patients; and (c) with a good modular medevac system, the planes in CRAF could quickly be configured for medical airlift missions—and then be reconfigured to their original role just as quickly. Thus, use of CRAF for medevac is a wise choice.

TABLE 5. COMPARISON OF CRAF-LRI PAX AND CARGO AIRCRAFT FOR MEDEVAC

PAX	Cargo
<u>Advantages</u>	
Has all "people" amenities	Faster conversion to airevac
Good medical environment	No backhaul of seats
Fleet capacity exceeds demand	Broad mission capabilities
<u>Disadvantages</u>	
Longer conversion time	Limited "people" amenities
Must backhaul all seats	Poor medical environment
Limited backhaul capacity	Demand exceeds capacity
Limited mission capabilities	

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

PLAN FOR CRAF UTILIZATION

General Requirements

As stated earlier, a medevac aircraft must offer certain features in order to provide adequate care for the patients being transported. In summary, these features are:

Normal "People" Amenities

- Cooling/heating
- Pressurization
- Lavatories
- Galley
- Sound insulation
- Cabin lighting

Medical Needs

- 60-Hz 115-vac power at each litter
- Therapeutic oxygen at each litter
- Emergency oxygen for patients and crew
- Medical storage area
- Medical crew seating
- Litter support system

To meet the minimum people amenities, an aircraft placed into medevac service should be one that comes with the first group of features (above) as an integral part of the plane's configuration. All passenger planes in the CRAF-LRI fleet have these features. Such is not the case for the cargo planes, however; and, during reconfiguration, as many of these features as possible should be added to the cargo planes.

Comfort Pallets. For military transports such as the C-141 and C-5, the most important people amenities (lavatories and food services) are provided with a piece of equipment called a buffet lavatory unit--or, more commonly, a "comfort pallet" (7). The comfort pallet, designed for use in a cargo airplane, has a galley, and the necessary plumbing and electrical facilities for operation in the aircraft. The unit also contains a portable water tank, refrigerators, ovens and hot plates, coffee makers, food serving trays, refuse containers, two lavatories, and a waste storage tank. When used in a C-141, one comfort pallet provides feeding and lavatory facilities for as many as 144 people for 18 hr (7).

The comfort unit is mounted on a standard 88- by 108-in. military pallet that is compatible with the 463L rail-roller system used in military transports. When used in a C-141 or C-5, the unit is positioned with: its longest dimensions running fore and aft in the cabin; and its back side

adjacent to the fuselage wall on the right side, thus allowing the unit to be connected to a 400-Hz AC outlet located in that wall (7).

If comfort pallets are to be used in CRAF-LRI cargo planes, a source of 400-Hz AC power will have to be made available to activate the unit. Additionally, because the spacing of the rail-roller system in a commercial cargo plane is different from that in the military system, some difficulty may be encountered in locking down the comfort pallet in a CRAF freighter.

Although the comfort pallet represents a reasonably good solution to the problems caused by a lack of lavatories and galleys on cargo aircraft, the current inventory of these units is limited and their effectiveness leaves much to be desired. As expressed by Acosta et al. (1):

The existing C-141 comfort pallets are at best marginal. They do not reflect the state-of-the-art technology, particularly the latrines and refrigerator, and are approaching the end of their life expectancy. One major area of concern is the common occurrence of noxious odors which may likely further compound patient problems. Installation of the new recreation vehicle type latrine or of an improved airline type latrine is deemed necessary. Oven capacity is considered adequate. Freezer/refrigerator storage space is adequate, but incorporation of an electrical refrigeration system would be beneficial, particularly at remote or field hospitals where dry ice is not likely to be available.

For a larger aircraft, such as the C-141B, even the oven capacity is now considered inadequate. Thus, the military transport offers only marginal features for medevac. The cabin has almost no sound insulation, the lighting is minimal, and the cooling-heating system is drafty and difficult to control. A commercial freighter presents about the same problems.

Medical Needs of Airborne Patients. For the medical needs of airborne patients, all equipment and materials must be placed on the airplane during reconfiguration, regardless of whether a military or commercial aircraft is used. At the present time, much of such medical equipment taken aboard on medevac flights has been especially designed to fit the airborne environment, including such limitations of the aircraft subsystems as electric power and oxygen. As a result, some of the equipment is marginal in performance, has a short utilization cycle because of being battery powered, or requires an excessive amount of medical crew attention.

By providing an improved system of modular medevac equipment, usable in any large airplane, not only will the size of the medevac aircraft fleet be increased by making possible the use of the CRAF-LRI airplanes, but the level of airborne patient care will be improved because of the opportunity to use more sophisticated medical equipment on medical airlift flights. Such a system has been designed, and is described in the following material.

The Modular Medevac System (MMS)

In the designing of the modular medevac system, concentration has been on the development of the "utilities infrastructure" of the system, as opposed to the improvement of such direct-care equipment as pumps, respirators, and monitors. In keeping with this approach, therefore, the major features of the resulting design fall into three categories: (a) equipment for holding litters in vertical stacks; (b) equipment for producing and distributing 60 Hz, 115/120 V AC electric power; and (c) equipment for supplying and distributing both medical and emergency oxygen. Each of these features is discussed separately in the following sections.

Litter Support System (LSS). The design of the litter system takes into consideration not only the minimum functional needs, but also some desirable attributes of an ideal system (1, 47, 55). The seven major features of the LSS are:

- a. Four-sided litter access and minimum dimensions of--
 - 13 in. between ends of two litters
 - 25 in. aisle between adjacent rows of litters
 - 18 in. vertical space between litters in same tier
- b. Litter height adjustable in 2-in. increments at each end
- c. No litter lower than 5 in. from floor
- d. Designed for a load of 250 lb/litter, and up to 4 litters high
- e. Requires minimum change to aircraft interior
- f. Maximum stowability and minimum weight
- g. Quickly installed, sturdy, and foolproof.

The system that resulted from this design effort is made up of a basic litter support frame, which consists of a vertical stanchion member attached to a horizontal base member. Two of the stanchion-base assemblies are then assembled into a single unit, joined by two cross members at the bottom and one at the top. This stage of the assembly sets up the spacing for the minimum 13-in. clearance between ends of litters. To accommodate rows of litter stacks, the dual stanchion-base assemblies are spaced an appropriate distance apart (80 in.-84 in.) in the airplane cabin and locked to the seat tracks by self-contained tiedown fasteners.

The litter stanchion assembly is to be fabricated from T-7076T6 aluminum. A preliminary stress analysis (details in Appendix A: Exhibit 1) shows that the assembly conforms to the requirements of MIL-A-008865A (Airplane Strength and Rigidity-Miscellaneous Loads), dated 31 March 1971 (55). Some uncertainty exists about forward load, because the research team was unable to do prototype testing of a litter stanchion. Moreover, because of the complexity of the calculations, determining the actual composite load from a paper study

only was impossible. Also, a question has arisen concerning structural integrity of the CRAF airplanes in a crash—a question which leads one to ponder the need for the litter system to withstand a 9-G longitudinal load as required in the military specification. Further study is needed before this issue can be resolved. For the other directional loads, however, the proposed design is acceptable.

Support of the litters is proposed to be handled with the same cantilever arms that are used with the C-9A litter stanchions. Several alternate designs for litter support arms were considered during this study but, to minimize changes to the present system and maximize the use of equipment already in inventory, the decision was made to go ahead with the C-9A arm. The general layout of the litter system is shown in Figure 1. (NOTE: All figures relevant to the text have been grouped at the close of the report, immediately following the "Selected Bibliography.")

A major concern of the research team, in designing the MMS was to develop a design that would be universal enough to fit into the C-141 and into all CRAF-LRI planes. Upon initial examination of aircraft interior dimensions and configurations, however, major discrepancies were found in clear ceiling heights of various types of aircraft, thus restricting the number of litters that could be placed vertically in a stack. Hence, although at least a 3-high stack is desirable (being about as high as may be conveniently attended by a medical crewmember), the existing low overhead clearance in some aircraft will allow only a 2-high stack. This condition exists in the B-707 and DC-8, and along the outboard rows of seats in the DC-10 and L-1011. For the B-747 and C-141, and along the inboard rows of seats in the DC-10 and L-1011, overhead room is adequate for a 3-high litter stack.

To accommodate this ceiling-height difference, two models of the litter stanchion have been designed--Model LSS-1, which is 70 in. tall; and Model LSS-2, which is 48 in. tall. Details of these two designs are shown in Figures 2-6. Both stanchion assemblies are identical except for height, and their design permits nesting while in storage, thus enhancing stowability. They are relatively lightweight (65-75 lb per assembly, less cantilever arms), will not easily be damaged, and have no loose parts. They are universal in that, with the exception of their height variation, they will fit into both long-range Air Force transports and all CRAF-LRI aircraft.

The cost of the litter stanchion itself is low. On the basis of a manufacturing quantity of 10,000, and average manufacturing costs in a non-aerospace environment, each litter stanchion should cost between \$96 and \$115. (Details of the cost estimate are in the Appendix A: Exhibit 2.) It should be noted that at least 2 stanchions are necessary, and this cost does not include the cantilever arms.

Oxygen System. The oxygen requirements of a mixed patient load on a medevac aircraft have been described earlier, but a summary of these details would be useful at this point. To meet the person-by-person needs, the system should be able to deliver (1)—

At a pressure of 50 ± 5 psig:

6.0 lpm for therapeutic masks
15.0 lpm for respirators
2.2 lpm for emergency use at each seat

At a pressure of 300 psig:

Sufficient quantity to refill the medical crew's walk-around bottles a number of times in a flight.

The total oxygen demand during a medevac flight can be calculated by using the foregoing figures for person-by-person needs, and multiplying these figures by the appropriate factors that apply to a specific patient-mix, aircraft-type, trip-length mission. In defining the maximum size and required type of oxygen system that should be developed as part of the MMS, the following hypothetical scenario was used--

Aircraft type	:	B-747 PAX
Length of flight	:	10 hr nonstop
Patient load	:	108 litters (60%) 71 ambulatory (40%)
No. therapeutic masks:		97 (90% of litters)
No. respirators	:	11 (10% of litters)
No. emergency masks	:	87 (includes 16 medical crew)
Emergency needs	:	5 hr (of one-half of flight)

For this scenario, the amount of gaseous oxygen required totals 506,142 liters, or about 50,000 liters/hr. For other types of aircraft or other missions, the requirement will be considerably less. Table 6 shows the total oxygen demand for the B-747 example just given, along with that for several other aircraft types operating over the same mission profile as the B-747.

Among the numerous ways of supplying oxygen on demand for life-support systems, the five most common are:

- a. Low-pressure gas cylinders
- b. High-pressure gas cylinders
- c. Molecular sieve separators
- d. "Chloric candles"
- e. Liquid oxygen (LOX) systems.

An explanation of each is given in the following discussion. The data concerning low-pressure and high-pressure systems are taken partly from Mazulewicz (36).

Low-Pressure Systems

In these systems, the oxygen is stored in lightweight cylinders at pressures less than 450 psig. For medical airlift applications, the most widely used low-pressure system is the portable (or walkaround) bottle that the medical crewmembers employ when moving around the cabin to attend to patients. Beyond this application, not much use is made of low-pressure systems, due to their low capacity and short service cycles (36).

TABLE 6. MAXIMUM OXYGEN DEMAND BY AIRCRAFT TYPE
UNDER A HYPOTHETICAL SCENARIO^a

Aircraft type	Respirators	Therapeutic masks	Emergency masks	Demand in liters of gas
B-707	3	31	25	155,250
DC-8-61/63	4	38	24	192,114
L-1011	7	61	50	315,900
DC-10	7	64	60	336,960
B-747SP	8	73	63	376,758
B-747	11	97	87	506,142

^a 10-hr nonstop flight, cabin depressurized 5 hrs, 60% litters, 40% ambulatory, 10% of litters use respirators, 90% of litters use therapeutic masks. Emergency O₂ to litters with therapeutic masks.

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

High-Pressure Systems

The cylinders used in these systems carry oxygen at 1,800 to 2,200 psig. However, their ability to retain gas at these pressures results from having thick walls which, in turn, make the cylinders quite heavy. This system offers very little improvement over the low-pressure system, except to reduce the number of cylinders needed for a specific volume of gas. For a long-range medevac flight, however, the weight of the necessary number of cylinders, as well as the hazard they pose due to the frangible regulator-cylinder connection, makes them less than desirable.

Molecular Sieve Separators

Sometimes referred to as "oxygen concentrators," molecular sieve separator systems generate oxygen by passing air through an absorption bed which separates the nitrogen from the oxygen. By reversing the gas flow through the bed at frequent intervals, oxygen is concentrated in a plenum and nitrogen is purged from the system.

Operation of a molecular sieve oxygen system requires a large volume of compressed air—at least five times as much as the amount of oxygen required. The compressed air supply must be produced at a high enough pressure to force the gas through the absorption bed and, in the case of the medevac requirements, must also be able to pressurize the plenum-stored oxygen high enough to enable the recharging, at 300 psig, of the medical crew's walkaround bottles. These combined factors require a size of compressor that, in larger systems, will be quite energy intensive—as high as 64 kW, in a system large enough to approximately meet the demand created in the B-747 scenario cited earlier.

Size and weight of large compressor-driven molecular sieve systems are additional considerations which affect the feasibility of this type of system for medical airlift. According to figures prepared by Clifton Precision (the life support systems division of Litton Industries), a single module of this type that is large enough to produce around 23,000 liters of gaseous oxygen per hr will be approximately 3 x 4 x 6 ft high, and will weigh from 1200 to 2500 lb, depending upon whether a reciprocating or rotary-type compressor is used. Since B-747 scenario will require two of these modules, the total resulting weight will be 2400 - 5000 lb.

One way to avoid this problem, and thus reduce the weight and the energy requirement in an aircraft application, is to be able to capture ram air (created by movement of the aircraft) or bleed air from engines (in the case of a turbine-powered airplane) to be directed through the system. The onboard oxygen generation system (OBOGS) of the B-1B, for example, uses engine bleed air as the input to the absorbent beds, thus providing a continuous supply of oxygen as long as the engines are operating. The advantage here, of course, is that the necessary oxygen is always available when needed; and the complexities of the system, as well as the large electric power requirement, are avoided. Using ram air would not be as effective in the medevac mission because of the need to maintain an oxygen flow even while on the ground.

Since a well-designed and well-maintained molecular sieve system has an "unlimited" lifetime, this type of oxygen supply deserves further study for application to the MMS. Presently, the CRAF airplanes have no way to take aboard enough ram or bleed air to operate a large molecular sieve system. Thus, an evaluation of feasibility of modifying a number of the CRAF planes for this purpose should be given a high priority in any program of research that follows this study.

"Chloric Candles"

A chloric candle is a mixture of chemicals that, when heated to a high temperature, emit oxygen. Traditionally regarded as a strictly emergency means of producing oxygen, these devices are commonly used aboard submarines as backup to main systems, to enable a crew to surface when main system failures occur. These candles are also used at the present time on the DC-10, B-767, and Airbus for emergency descent after loss of cabin pressure.

Although several formulations of materials are used in chloric candles, a typical one might be as follows:

<u>Ingredient</u>	<u>Percent of Mix</u>
Sodium Chlorite (NaClO_2)	86.3
Manganese Dioxide (MnO_2)	4.8
Sodium Dichromate ($\text{Na}_2\text{Cr}_2\text{O}_7$)	0.2
Magnesium Powder	5.8
Water	2.9

Other "recipes" substitute sodium chlorate (NaClO_3) or sodium perchlorate (NaClO_4) for the sodium chlorite. The volume of candle required per unit of oxygen is about one-third less with the sodium chlorate and about one-half as much with the sodium perchlorate, when compared with using sodium chlorite (as already listed).

The amount of candle required per unit of produced oxygen varies, as just stated; and, for the foregoing formula, about 3.5 g of material are required to produce 1 liter of oxygen at standard temperature and pressure. The resulting mass can be significant when the amount of oxygen required is large. For example, in the hypothetical scenarios in Table 6, the mass of candle needed could range from 3 short tons to as much as 6 with the B-747, and from 1 short ton to 2 with the B-707. Also, note that these figures include neither the weight of the containers that enclose the candles, nor the weight of a compressor.

Besides weight, other problems are faced in using a chloric candle, e.g., the amount of heat generated; the hazards associated with having something burning aboard the aircraft; and the problem of filtering the smoke and other combustion products out of the oxygen stream. The amount of heat produced as

a byproduct of generating 500,000 liters of oxygen by the chloric candle method, for example, amounts to approximately 22 million BTU.

In considering the viability of the chloric candle method for the production of oxygen aboard a medevac flight, the best application of this type system would probably be as a backup to other systems designed for routine use.

Liquid Oxygen (LOX) Systems

LOX systems, mainly because of their space and weight savings, are the type most commonly used in military airplanes. A LOX system contains liquified gas in a double-walled container, along with a system to heat and re-gasify the oxygen upon demand. Through proper sizing of the system and use of the appropriate filling and pressure-relief valves, the boil-off of the LOX can be kept to a low of 1 percent per 24-hr period, with no loss at all during the first 72 to 96 hr after filling (while in a standby mode).

At 804 liters of gaseous oxygen to 1 liter of LOX, the hypothetical scenario in Table 6, for a B-747, would require 629.5 liters of LOX plus a boil-off allowance of 1 percent (assuming a 1-day flight between a theater recovery base and a CONUS hospital site), or a total of about 636 liters of liquid. If a standard 210-liter system (MVE Model VLPB-210L or VL-210L) is specified, 3 of these modules--along with the proper delivery system (hoses, regulators, and connectors)--would suffice to meet the demand of the B-747 example. Each of the modules would have a diameter of 24 in. and a height of 55 or 57 in., depending on the model selected. Weight of each module would be a maximum of 740 to 790 lb, which includes the tare of the system plus the weight of the liquid at 2.5 lb/liter. Total system weight for the B-747, exclusive of hoses and litter-position-connectors, would be 2,220 to 2,370 lb.

Use of LOX system for the MMS would require access to a large supply of liquid oxygen at one stop of a medevac flight. Since a well-designed system would have no evaporation losses for 72 to 96 hr, an operating medevac system could be set up to provide for loading a filled system aboard the CRAF aircraft in CONUS for use during a return movement of patients back to CONUS within one week.

Other Oxygen Systems

Advances in the production of oxygen are underway; and some of these, if they prove to be workable and reliable, could well render obsolete some of the systems just discussed. One of the new systems is offered by ROMEK of College Station, Texas.

Few details are available for the ROMEK equipment, because the patent application is still pending. Reportedly, for a system large enough to produce 50,000 liters/hr of gaseous oxygen at 50 psig, the module will: occupy approximately 16 ft³ of space, weigh about 120 lb plus the weight of the power unit, and require 7 hp to operate. Compression of the output to 300 psig, for recharging of the medical crew's walkaround bottles, will

require an additional, small compressor. ROMEC has indicated that direct contact will be made with the sponsor to discuss this system further.

Electric Power System

The electrical load on a typical medevac flight will be the total of various demands. Direct-care medical equipment (such as suction pumps, defibrillators, and monitors) make up a small part of the load, while electric power converters and air compressors have fairly large requirements.

The majority of the electrically driven equipment aboard a medevac plane requires an input of 60 Hz 120 V AC power. Normal sources of power on military and civilian transport planes, however, are engine-driven generators which typically produce 400 Hz 120 V AC power. Thus, a problem exists in changing the frequency of the power from 400 Hz to 60 Hz, a change made by means of a solid-state converter. This device receives an input of 400 Hz electricity from the integral aircraft system, and provides an output of 60 Hz power at the same or some other voltage.

The total electrical load placed upon the 60-Hz system fluctuates constantly as equipment comes on line or is turned off in response to random demand. No data exist that will give a plot of electrical demand peaks and valleys on a typical medevac flight; however, certain assumptions must be made regarding demand in order to design a system that has the load capacity to handle most situations.

"Design Note 6B1," of AFSC Design Handbook 2-2, specifies that a load capacity of 200 amps at 120 V AC should be available at each litter tier (19). Since most medical equipment has solid-state electrical systems, such a capacity would seem to be overly redundant for the actual demand. Acosta et al. (1: pp. 4-10) defend this view by discussing the need to have a line capacity, at each litter tier, large enough to carry the motor-starting load of any type of aeromedical equipment. The maximum load is given as 3.5 kVa at 120 V, which equates to approximately 30 amps.

For the determination of average loads, actual experience was considered to be the most reliable indicator. As just reported, no published data were found that would provide information on historical usage patterns. However, interviews with USAFSAM personnel (47) revealed that, according to experience gained during many C-9A flights, an average maximum demand of 1 amp can be expected at each litter position (3 amps for a 3-high tier). These same sources also reported that the simultaneous occurrence of peaks from all litters was rare.

In addition to the AC load, those aircraft on which Vickers Aircraft Transport Isolator can be used (all CRAF PAX-type airplanes are excluded due to door-opening size restrictions) must have a 28-V DC outlet in the cabin. For driving portable 400- to 60-Hz converters, several 400-Hz, 3-phase AC outlets should also be somewhere in the cabin.

Regardless of the demand for electric power, such a demand can be met only if sufficient power is available on the airplane to operate all essential aircraft systems and still have a surplus of capacity sufficient to cover the

average demand and the transient peaks. The wide-body airplanes in CRAF-LRI account for some 89.6 percent of the potential medevac capacity of the entire LRI fleet; and, on these planes, large amounts of surplus power exist, as shown in Table 7:

TABLE 7. ELECTRIC POWER SYSTEM CAPACITIES^a

Aircraft type	Power generated	Total usage with galleys	Net power available (kVa)	Medevac needs ^b	Surplus power
B-747	240	166	90	13	77
L-1011	270	167	90	8	82
DC-10	270	165	85	9	76

^a Does not include that available from APU sources.

^b Based upon maximum 60/40 load.

SOURCE: Trans World Airlines, Kansas City, MO, and Douglas Aircraft Company, Long Beach, CA, 1983

The basic power systems on all of these aircraft are 3-phase, 4-wire "wye" AC systems, having a nominal voltage of 115/120 V and a nominal frequency of 400 Hz. The DC power system in each aircraft is a 2-wire, grounded system having a nominal voltage of 28 V. Distribution of power is through AC and DC buses, and provision is made for paralleled operation of all of the generators.

The B-747 has 4 identical, engine-driven, 60-kVa, 115-V, 400-Hz generators. The L-1011 has three 90-kVa, 120/208-V, 400-Hz units. The DC-10 is equipped with three units rated at 90 kVa at 115 V and 400 Hz. Each of the airplanes also has one or more auxiliary power units (APU)—typically small gas turbines—that provide electrical power and other utilities (such as air-conditioning) while the aircraft is parked with the main engines shut off. Each of these auxiliary power units provides an amount of power equal to that supplied by one engine-driven generator. Since the total medevac load is less than the output of one engine-driven generator, the availability of power while on the ground should be more than adequate for the needs of medevac (Table 7).

Under normal operating conditions (that is, with the galleys in use), the amount of power available to operate the modular medevac equipment ranges from 74 kVa (617 amps) on the B-747, to 105 kVa (875 amps) on the DC-10 (Table 7). Because patients accepted for medevac airlift normally have been stabilized, their requirement for support from electrically driven equipment during the flight should not be excessive. Even in a catastrophic, worst case scenario, however, in which every patient's condition starts deteriorating enroute, the largest load of litter patients anticipated (108 on a B-747 in a 60/40

mode)--each requiring a maximum of 1 amp of power per litter, or 108 amps total--could be accommodated with enough reserve to handle also the demand from an energy-intensive molecular sieve oxygen system (about 500 amps).

Since the probability of occurrence of such a catastrophic scenario is extremely low, a power system designed for the MMS does not need to be as large as such a situation would dictate. In the design of the system, however, the standard 400-to 60-Hz converter now in Air Force service, the Unitron PS-75-426-1, was found to meet the requirements of the projected patient loads. Due to its low weight, ruggedness, reliability, and operating parameters, this converter is ideally suited for use with the MMS. By selection of this unit, several significant advantages are gained in the areas of cost, availability, and maintainability.

The Unitron converter has an input requirement of $115/200 \pm 20$ V rms, 3-phase, 360/400-Hz AC power. The unit's rated output is 3.5 kVa of single-phase, 115 ± 3 V rms at 60 Hz. By use of one converter for each longitudinal row of 3-high litter tiers, the system will be more than adequate for the MMS in any of the CRAF-LRI aircraft operating in a 60 - 40 patient-mix mode. When equipped with a 150-ft distribution cable, made from 10-gauge wire and containing a moulded-in duplex receptacle at each litter tier location, one electric power conversion module will only weigh about 100 to 105 lb. At this size, handling of the unit into and out of an airplane can easily be accomplished.

The feasibility of depending upon the aircraft electrical system to provide all of the power needed for a loaded medevac flight is affected in a "lost engine" scenario. In Table 8, figures are listed to show the net power available in engine-loss scenarios for each of the wide-body aircraft. No consideration is given to the effects on performance, flight duration, or safety that are the result of engine losses; however, the assumption is that power to the galleys would be cut off in an engine-out situation.

Other Considerations

In planning for medevac utilization of the CRAF-LRI fleet, several areas of concern have arisen regarding some ancillary aspects of implementation. Each of these aspects requires a brief explanation to explain its possible impact upon the program.

Backhaul of Equipment. When PAX-type aircraft are used for a medevac mission that includes litter patients, a number of seats must be removed to make room for the litter supports and litters. If the airplane is scheduled to return from CONUS with troops, the seats that were removed must be carried along on the medevac flight to CONUS. A space problem can arise if many litters are carried, due to the bulk (not weight) of the seats. Only the B-747, with its unusually large lower lobe compartment, affords enough space to carry the seats displaced by a maximum 60-percent mix of litter patients, along with the patients' personal baggage. The problem is that the typical airline seat is a rigid assembly—including the back which, in most cases, does not fold down. Also, the blue airline-type seat used by MAC is no more compact than any civilian airline seat.

Possible solutions to this problem include: (a) dedicating certain airplanes to medevac, and leaving the seats out until the emergency is over; (b) developing a more compact seat, or one that is foldable; or (c) carrying only 2 litters in a stack, both located above the top of the seat backs, thus leaving all seats in place. Further evaluation of this problem should be carried out.

TABLE 8. ELECTRIC POWER AVAILABILITY IN ENGINE-LOSS SCENARIOS

Aircraft type	Medevac power need	Net power available with:			
		4 engines	3 engines	2 engines	1 engine
		(kVa)			
B-747	13	74	104	44	None
L-1011	8	--	103	103	13
DC-10	9	--	105	100	20

NOTE: Galleys are operated with all engines running, but are turned off with loss of one or more engines.

SOURCE: Table 7.

Rafts and Life Jackets. A question exists as to whether or not rafts and life jackets of a suitable type, capacity, and quantity will be on the CRAF planes used for medevac. Investigation of this issue has resulted in the following information:

- a. All airplanes in the CRAF-LRI are overwater-qualified and carry the number of rafts required by the FAA for the maximum number of passengers that the type of airplane is certified to transport. Since a medevac load will consist of considerably fewer persons than a maximum commercial load, the raft capacity should be more than adequate.

- b. The special life jackets required for litter patients are a standard AF inventory item and all medical crews have instructions to be sure enough of these are loaded aboard a medevac flight to meet the needs of the patient load.

Floor Load Capacities. Various types of oxygen and electric power modules might be placed aboard a CRAF-LRI airplane for a medevac flight; but the heavy weight of some of these types has raised a question concerning floor loads. For the narrow-bodied CRAF planes (B-707 and DC-8), a load of 200 lb per square foot (lb/ft^2) is the maximum that can be safely sustained in the main cabin. With the wide-body types (B-747, DC-10, L-1011), due to the wider spacing between fuselage structural members, maximum loads should not exceed a range of 500-1,000 lb per foot (lb/ft) running longitudinally through the main cabin (equal to about 100 lb/ft^2).

Based upon a bearing load of $100\text{--}200 \text{ lb/ft}^2$ for the Clifton Precision molecular sieve unit, and 190 lb/ft^2 for a LOX system, some type of pallet should be used for mounting each of these systems in order to spread the loads over a large floor area. A 38 X 50-in. pallet, which would fit quite easily through any of the PAX doorways, could be used to reduce the LOX system's floor loading figure down to a $50\text{--}60 \text{ lb/ft}^2$ range. Because of its size (3 ft X 4 ft), however, the molecular sieve unit's floor load could not be reduced to any great extent. Use of pre-cut plywood floor kits would help alleviate floor load problems.

Civilian Flight Crew. Under existing MAC contracts, call-up of CRAF planes would include the civilian crews as well as the airplanes. Aside from the cockpit crew, as many as a dozen civilian flightcrew members could be aboard the aircraft while in operation. Seating for these persons has been included in all patient capacity figures. Inasmuch as flight attendants are required to have training in emergency medical care, they could probably be used in a productive way that would reduce the necessary size of the USAF medical crew.

MODULAR VS. MODIFICATION

The proposed use of the airplanes in the CRAF-LRI fleet for medical airlift has many positive aspects, most of them associated with an improved patient environment, better availability of aircraft as compared with those of the military fleet, and the enhancement of military airlift's ability to perform its mission. For CRAF to be used in this role, however, requires the development of a system for providing (aboard the planes) the minimum amenities and medical care systems necessary for maintaining the well-being of the patients being transported.

The existing system used with military transports cannot simply be transferred to civil transport "as is"; for the system depends upon a number of features, available on the military planes (such as tiedowns and ceiling anchors), that are not found on the civilian planes. Also, taking into account the real-world economic and political elements involved, utilization of the CRAF planes must be accomplished in a way that least affects the owners' use of them. In other words, the planes should not be modified in any manner that would reduce their revenue-earning potential or necessitate a long lay-up.

The best solution to this dilemma is to develop a medical care system that can be carried aboard a CRAF plane and that, with the equipment found aboard, can be used to set up and tie down a completely integrated, fully operational, airborne hospital ward. Minimal modification to the plane would be required with this approach; and, in exploring this proposed system with several airline companies, we found that the work that would be done is generally acceptable from their perspective.

The proposed modular medevac system (MMS) recommended for adoption into the Air Force strategic airlift network will consist of: (a) the Litter Support System described earlier; (b) a standard 210-liter liquid oxygen module with distribution hose system; (c) a Unitron 400/60-Hz power converter with distribution cable system; (d) comfort pallets for cargo aircraft; (e) a Transportable Airborne Therapeutic Station (TATS); (f) biological refrigerators; and (g) other medical equipment and materials. Final distribution and administration of oxygen would be with the existing C-141 therapeutic oxygen manifold distribution system (TOMS) except for ventilators, which would need a direct oxygen line.

Modification of individual airplanes to utilize the MMS will be minimal, and will require relatively minor work. Without a tail-number by tail-number analysis of each plane in the fleet, the only modifications that appear to be required are the installation of several 400-Hz, 3-phase, 115-V AC outlets, near the front of each cabin, into which to plug the 400-to 60-Hz converters--plus the addition of a weathershield of some type at each entry door of each airplane. A close look at each airplane would be required in order to identify further changes that might be necessary.

On the other hand, major modifications would be required if the medical airlift reconfiguration of CRAF airplanes is attempted without the MMS. Yet, the only difference between an airplane using the MMS and one that has been reconfigured through modification is the location of the carry-aboard utilities and their distribution systems. If the modular configuration were used, the entire oxygen and electrical system would be placed in the main cabin of the airplane, with a distribution system made up of hoses and cables being laid along the tops of the litter supports.

In the modifications mode, only the distribution system would be on the main deck, while the oxygen and electrical equipment would be located in the lower baggage area. The distribution system could be the same as in the modular method, or could be made of piping and wiring placed inside the floor, wall, or ceiling of the cabin. In terms of providing for the basic oxygen and electrical needs of the mission, neither system would be superior to the other.

For both approaches, the heavy equipment used for supplying oxygen and 60-Hz power would be loaded onto the aircraft only when a medevac mission was to be flown. In the modified airplanes, however, the hookup and distribution system that was installed represents a long-term weight penalty for which someone, probably the Government, would have to pay. If the MMS approach is taken, the only weight penalty will be from 3 or 4 electric outlets installed to provide 400-Hz power for the 400/60-Hz converter.

Application of the MMS to the aircraft in the CRAF-LRI fleet results in a certain capacity of patients per airplane type. Shown in Table 9, and in Figures 7-11, are the results achieved if a ratio of patient types equal to 60-percent litter and 40-percent ambulatory is used in loading each plane--and if space is set aside for the seating of medical crewmembers, and for the carriage of TATS units and other medical equipment.

In summary, the MMS appears to offer significant advantages over any other program of major modification. Because the MMS is almost totally removable from the airplane, the cost is considerably less than with a modification program; and, in realistic terms, the modular approach is more likely to "fly" in a political sense.

Costs of the Two Systems

Costs of the components of the MMS have been fairly easy to define, but securing reasonably good estimates of cost for the major modifications of the CRAF airplanes has been beyond the scope of this study. Airline and aircraft company representatives have indicated that lengthy, major efforts would be necessary to compile such figures.

In order to obtain a "ball-park" number to use in approximating the cost difference, aircraft company personnel were asked to give some type of estimate. For all three wide-bodied airplanes, the estimates were very similar. Because of the age and limited medevac payload capabilities of the narrow-bodied types (B-707 and DC-8), no cost estimates were sought for modifying them.

TABLE 9. MEDEVAC PATIENT CAPACITIES WITH CRAF USING A 60/40 RATIO
(60% LITTER: 40% AMBULATORY)

Aircraft type	No. of airplanes	No. of litters	No. of ambulatory patients ^a	Patients per airplane
B-747	134	108	71	179
DC-10	78	72	50	122
L1011	27	68	40	108
B-747SP	13	81	53	134
B-707	13	34	20	54
DC-8-50/62	8	34	21	55
DC-8-61/63	50	42	24	66

^a Excludes seating used by medical crew and civilian flight crew.

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

A rough comparison of costs for the two configuration approaches is given in Table 10. Although the figures for the costs of aircraft modifications may be off by a large factor, the costs are considered by the sources to be minimums; thus, the cost advantage of the MMS would be even greater with more accurate data. In Table 11, the cost of the MMS per patient is shown for each aircraft type in the CRAF-LRI fleet.

TABLE 10. COST COMPARISON OF MODULAR AND MODIFICATION
APPROACHES USING A B-747 EXAMPLE

Item description	Estimated costs	
	Modular	Modifications
Litter Support System (less cantilever arms)	\$4,945 (43 units)	\$4,945
LOX System (with hoses) Piping Manifold	\$60,000 (3 modules) —	\$60,000 \$500,000
Power System (with cables) Wiring System	\$30,000 (4 converters) —	\$30,000 \$100,000
Vacuum System	(use portable pumps)	\$500,000
Total Cost	<u>\$94,945</u>	<u>\$1,194,945</u>
Cost per patient of payload (60/40 mix)	\$530	\$6,676

SOURCE: Center for Strategic Technology, Texas Engineering Experiment
Station, Texas A&M University System, College Station, Texas,
1983.

TABLE 11. COST OF MODULAR MEDEVAC SYSTEM PER PATIENT
OF CAPACITY USING A 60/40 RATIO
(60% AMBULATORY: 40% LITTER)

Aircraft type	Cost per patient
B-747	\$682
DC-8-61/63	\$868
L-1011	\$616
DC-10	\$546
B-747SP	\$640
B-747	\$530

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

Rank Order of CRAF for Medevac

With the known information about the CRAF-LRI fleet, the airplanes for medevac utilization can be rank-ordered on the basis of numerous criteria, some of which are quantifiable. Disregarding quantification, the importance of each factor in establishing an order of call-up may vary, depending upon the circumstances at the time of call-up. In one situation, for example, patient comfort might be more important than cost of operation; at another time, reducing the number of airplanes operating in the traffic control system might take precedence over speed of turnaround. Rank-ordering the airplanes ahead of time thus becomes a matter of judgment on the part of the person or persons doing it.

Some of the factors that probably should be considered in any rank-ordering exercise are:

- Number of patients per aircraft
- Reconfiguration cost per patient
- Operating cost per patient-mile
- Number of aircraft per 1,000 patients
- Quality of patient environment by type
- Availability with known airlift shortfalls
- Turnaround time by type
- Fuel consumption per patient-mile
- Range, in nautical miles, by type
- Block speed by type.

Quantification alone is not the only source of a solution to the problem. For example, the fuel consumption per patient mile varies: from 0.08 gallons for the B-707, to 0.04 gallons for the B-747. This difference might be

insignificant in a wartime scenario, but very important during an austere peacetime period or during an oil embargo. The fact that the B-747 can carry more than three times as many patients as a B-707 (179 vs. 54 in a 60/40 mix), thus resulting in only a third as many aircraft flying in the MAC traffic-control network, could be more important than fuel savings in many scenarios.

For the purpose of this study, a rank-ordering analysis has been conducted. The following factors were considered most important:

1. Quality of patient environment (PAX vs. cargo)
2. Capacity, number of patients, 60/40 mix
3. Number of each type aircraft (common configuration)
4. Per patient cost of modular medevac system
5. Relative ease of reconfiguration (PAX vs. cargo).

The results of this analysis are presented in Table 12:

TABLE 12. RANK ORDER OF CRAF FOR MEDEVAC SUITABILITY

Rank	Aircraft type	Number of airplanes ^a	Number of patients ^b
1	B-747/B-747SP PAX	111	19,284
2	DC-10/L-1011 PAX	93	10,968
3	B-747/DC-10 CARGO	48	7,908
4	B-707/DC-8 CARGO	61	3,782
5	B-707/DC-8 PAX	10	660

^a From 1 October 1983 "CRAF Capability Summary"

^b From Table 9.

SOURCE: Center for Strategic Technology, Texas Engineering Experiment Station, Texas A&M University System, College Station, Texas, 1983.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The concept of using the aircraft of the CRAF-LRI for intertheater aeromedical evacuation (medevac) has considerable merit, and deserves to be included in the U.S. Air Force contingency plans for wartime scenarios. Unquestionably, in view of the present shortfall in strategic airlift capacity, the addition of CRAF to the fleet would improve our rapid response capabilities significantly.

Because of their existing configurations, however (especially the absence of litter supports and medical oxygen systems), the CRAF cargo and PAX planes cannot be used for medevac unless modified in a satisfactory or effective manner. To prepare the planes for this role requires that they be outfitted with various types of special equipment and materials that will allow skilled medical personnel to administer a reasonable level of nursing care to the ill and injured patients aboard the airplane.

Much of the direct-care equipment (pumps, monitors, etc.) and medical supplies can be easily carried aboard any large transport aircraft. However, other resources--such as litters for the seriously ill, oxygen for those with hypoxia, and electric power of the right type to operate equipment--are not readily available on any airplane, military or civil, except the C-9A. To provide these items requires a special effort, usually reconfiguration of the airplane. Reconfiguration can be done by permanently modifying the airplane, or by using some type of carry-aboard equipment that is easily set up and then removed after the medevac mission has been completed.

From the analyses and calculations conducted during this study, we have concluded that the best answer to the question of utilizing CRAF-LRI for medevac is to use a modular system like the one described in this report. The MMS meets the total needs of aeromedical nursing when used in conjunction with the TATS and other direct-care equipment and supplies already in the Air Force inventory. MMS supplies the medical "utilities" of oxygen and electric power, is quick and easy to set up, requires minimum change to the aircraft interior, is basically foolproof in its installation, and can be used in all CRAF planes as well as in both the C-5 and the C-141.

Opposed to the MMS approach is the concept of aircraft modification. This concept would provide the necessary "utilities" for medical care by permanently modifying each airplane to add built-in piping and wiring for the oxygen and electrical systems, and possibly, adding ceiling or wall attachment points to support litters. Such a system would also include the installation of hookup points in the lower baggage area of each plane where carry-aboard oxygen generators and electric converters could be loaded and "plugged in" at the start of a medevac assignment, only to be removed after the assignment is finished.

The modification approach is not only much more expensive than a modular system, like the one proposed here, but offers nothing in terms of

effectiveness at the point of service delivery that is not offered by the MMS. In addition, the real-world constraints on having major modifications made to an airplane that is in active commercial service effectively preclude this work being done on large scale.

Recommendations

In order to implement the use of CRAF-LRI aircraft in medevac, a detailed plan and the necessary equipment must be made ready. Before the detailed planning can be conducted, equipment design must be finalized and procedures for its use must be worked out. In addition, decisions have to be made on the approach, modular or modification, to be followed; and, from this decision, moves must be made to proceed with the modifications (if any) to be made on selected airplanes.

Some specific tasks that should be undertaken as a part of the implementation program are:

- a. Equipment and procedures for the enplaning/deplaning of patients transported in CRAF-LRI aircraft must be developed. Should enplaning/deplaning take place at cargo terminals? Is new equipment necessary, or can existing equipment (forklifts, galley service trucks, "Dulles" type transporters) be modified? What are the costs and other details? The USAF Surgeon General's office has prepared a SON (Statement of Need) on this subject, but no study has yet been done (22).
- b. Access into CRAF-LRI aircraft for Stryker and modified-wedge frames needs to be evaluated plane-by-plane. Although this aspect is not perceived to be a serious problem, questions about access need to be evaluated on a tail-number by tail-number basis because of the existing variations in configuration.
- c. Prototype evaluation is needed for the LSS equipment, LOX module, and electric converter system. Can the LSS meet the ultimate loads of MIL-A-008865 A (ref. 55)? What is the size and weight of the LOX module? Can the Unitron converter be reconfigured for one output (instead of two), and can it be mounted in a frame that will also contain a 150-ft conductor on a reel?
- d. Detailed study and cost estimates are needed for adding the 400-Hz outlets in the aircraft cabins to power the 400/60-Hz converters.
- e. Analysis is needed of the feasibility of providing ram or bleed air to the cabin or lower lobe areas of CRAF planes. If this procedure proves feasible, then research into an efficient molecular sieve oxygen system could be undertaken.

- f. Development of an improved cantilever litter support arm is needed. The present C-9A arm is a complex (and probably expensive) assembly. The design and development of a cheaper and lighter version should be possible.
- g. A tail-number by tail-number evaluation of the CRAF planes, to inventory the specific requirements of each for medevac reconfiguration, is needed to identify special problems.
- h. The Federal Aviation Regulation (FARs) pertaining to emergency exits should be examined and evaluated to see if waivers are needed. If all exits on CRAF planes are kept fully accessible, the patient capacity of all the planes will be significantly reduced. But, if the FARs tie the number of exits to the number of persons aboard, then some of these openings could be blocked.
- i. An evaluation should be made of the feasibility of dedicating certain CRAF planes to medevac. If possible, such a plan would allow modification of only the medevac-designed planes and, in use, would allow them to be set up in a medevac configuration full-time until the emergency is over. This step would eliminate problems of seat and equipment backhaul, would reduce turnaround time to a minimum, and would mean less wear and tear on the airplane and the equipment. Flying empty from CONUS to the theater recovery base would be no less efficient than flying empty in the other direction, as is currently done (43).
- j. An investigation of the design for weathershield that could be added to CRAF planes in advance is needed.
- k. A design study of seats with better stowability is needed to reduce backhaul problems on medevac missions.

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FIGURES 1 - 11

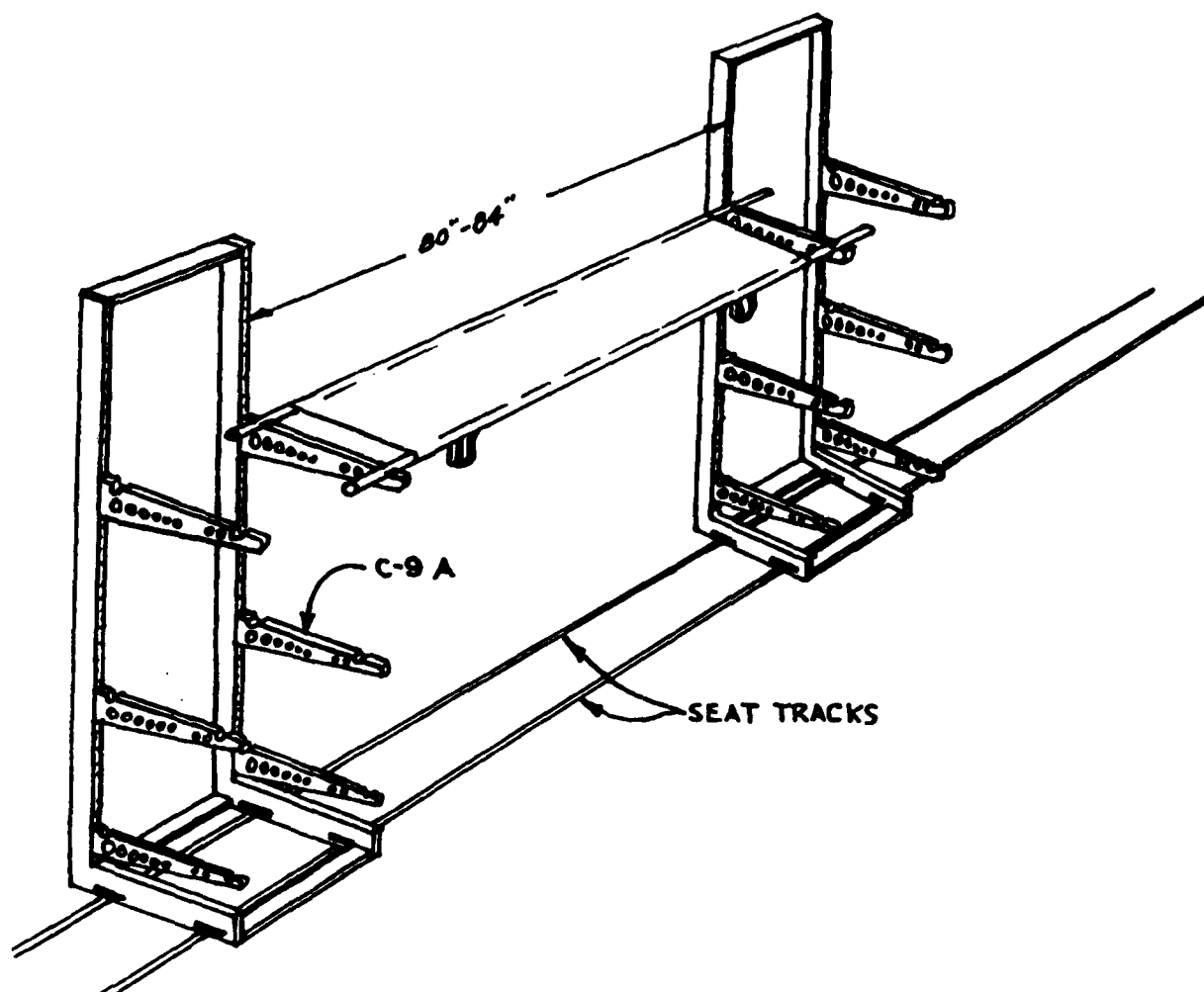


Figure 1. Litter Support System, Model LSS-1. (SOURCE: Center for Strategic Technology, Texas Experiment Station, Texas A&M University System, 1983)

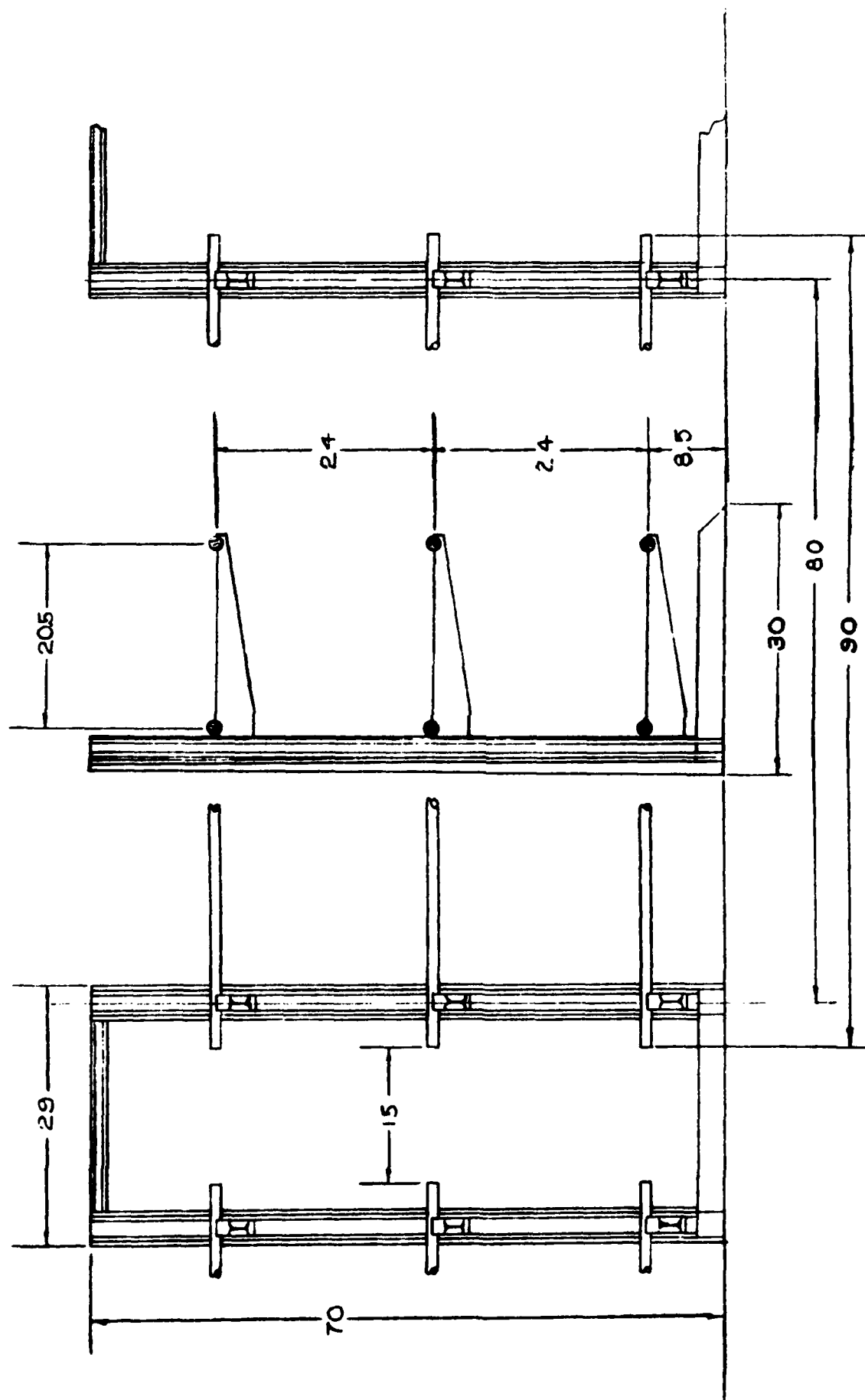


Figure 2. Model LSS-1 litter stanchion.

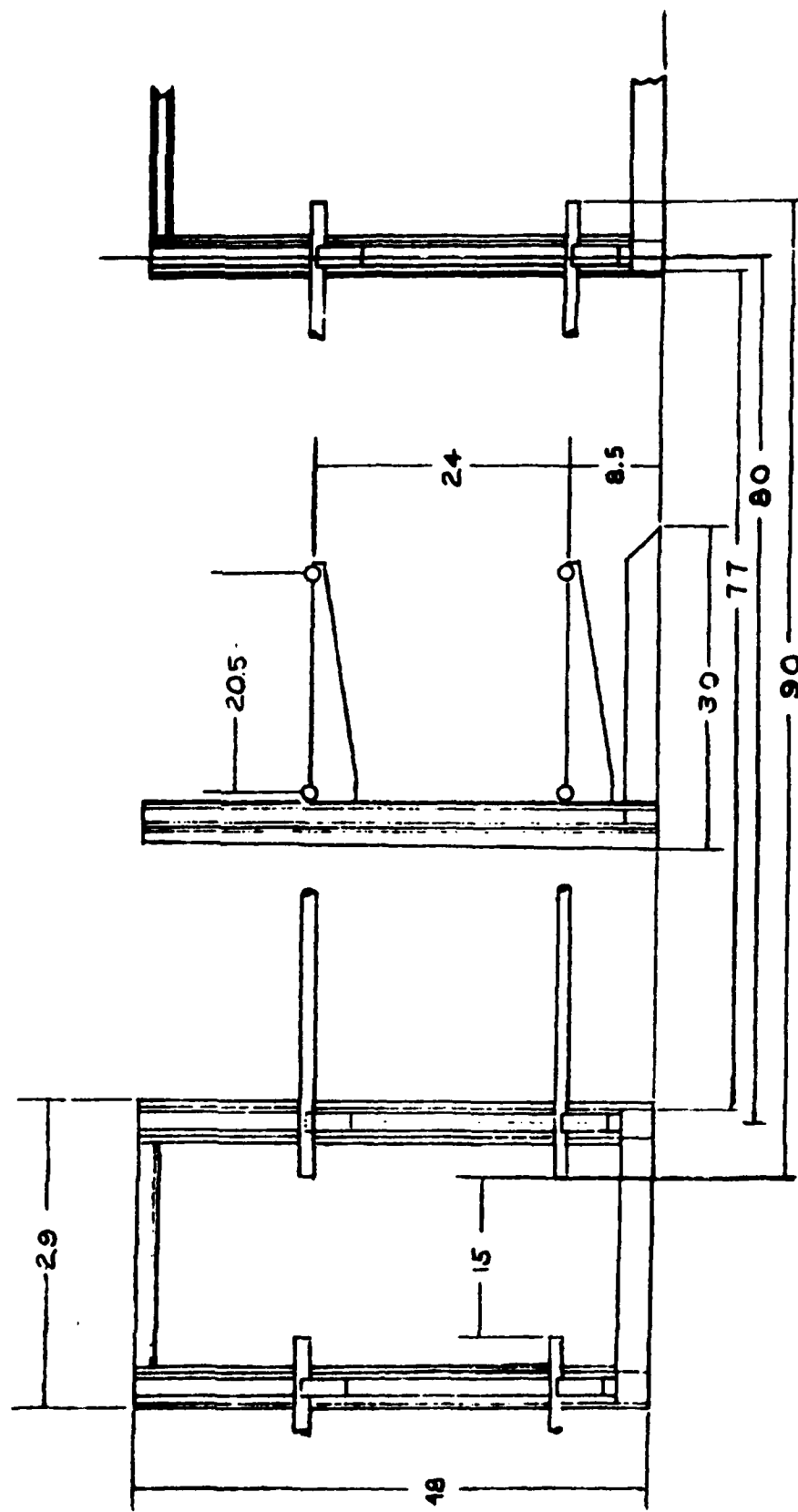


Figure 3. Model LSS-2 litter stanchion.

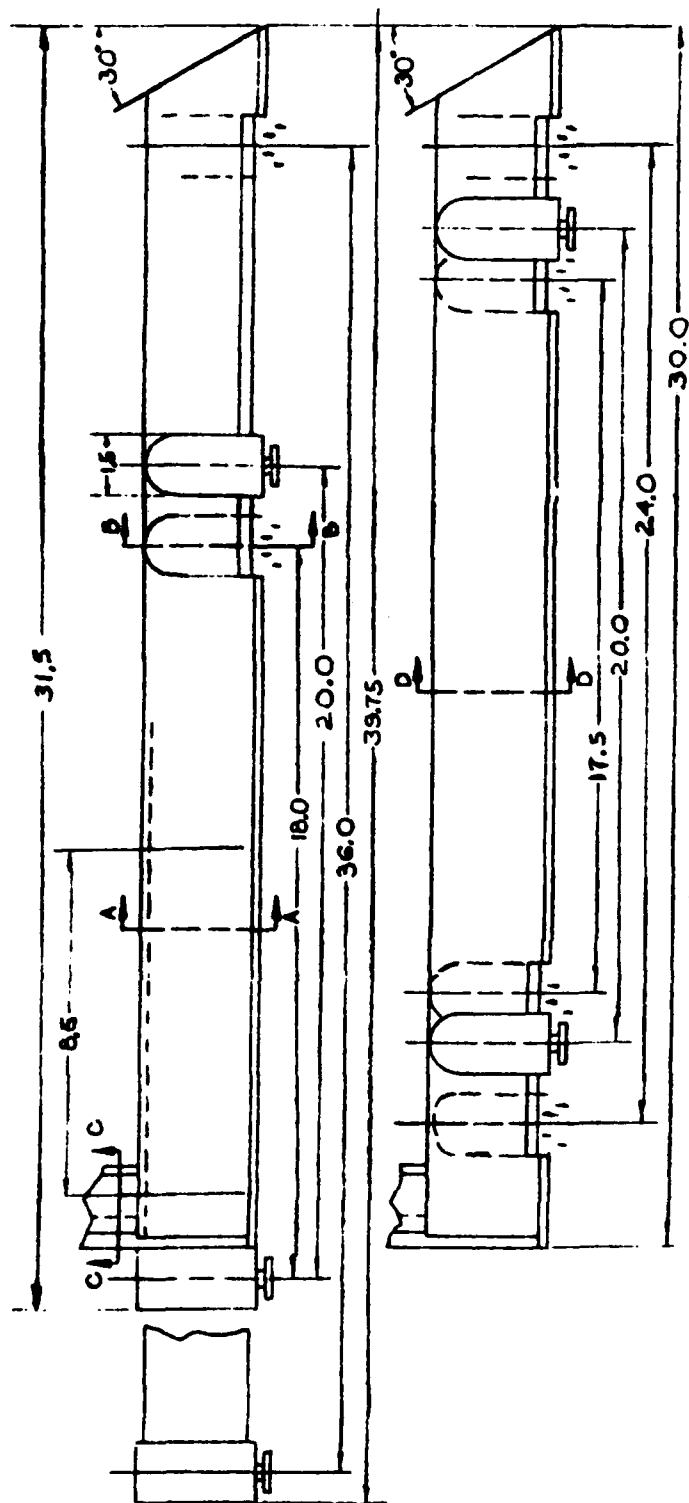


Figure 4. Litter stanchion details.
(Continued on facing page)

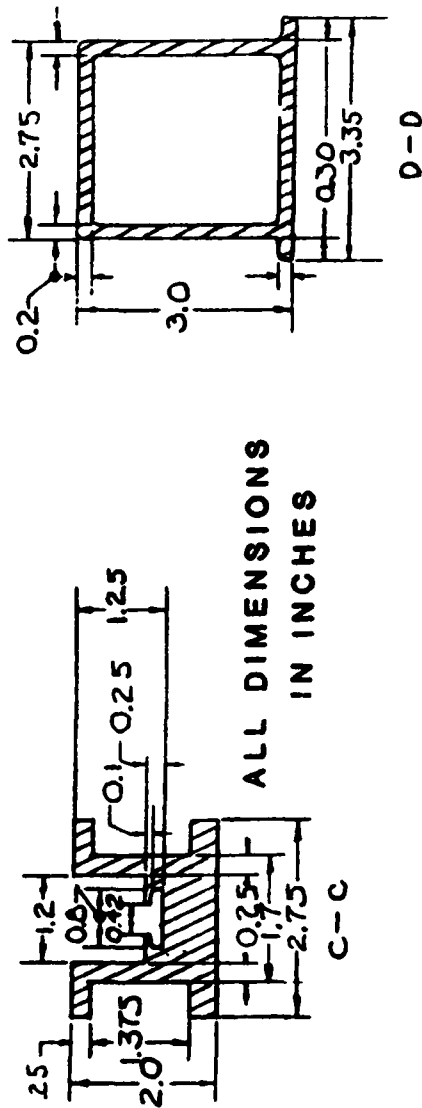
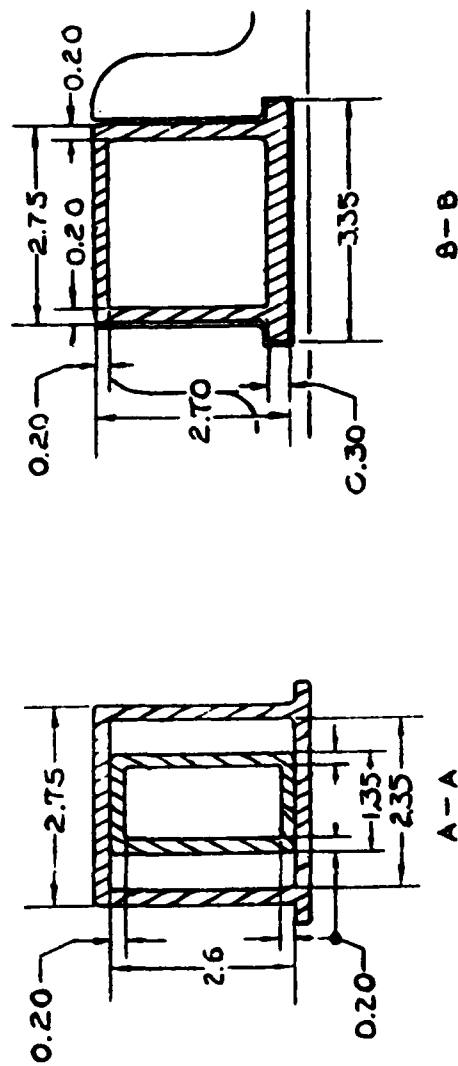


Figure 4 (Continued from previous page): Views A-A, B-B, C-C, and D-D.

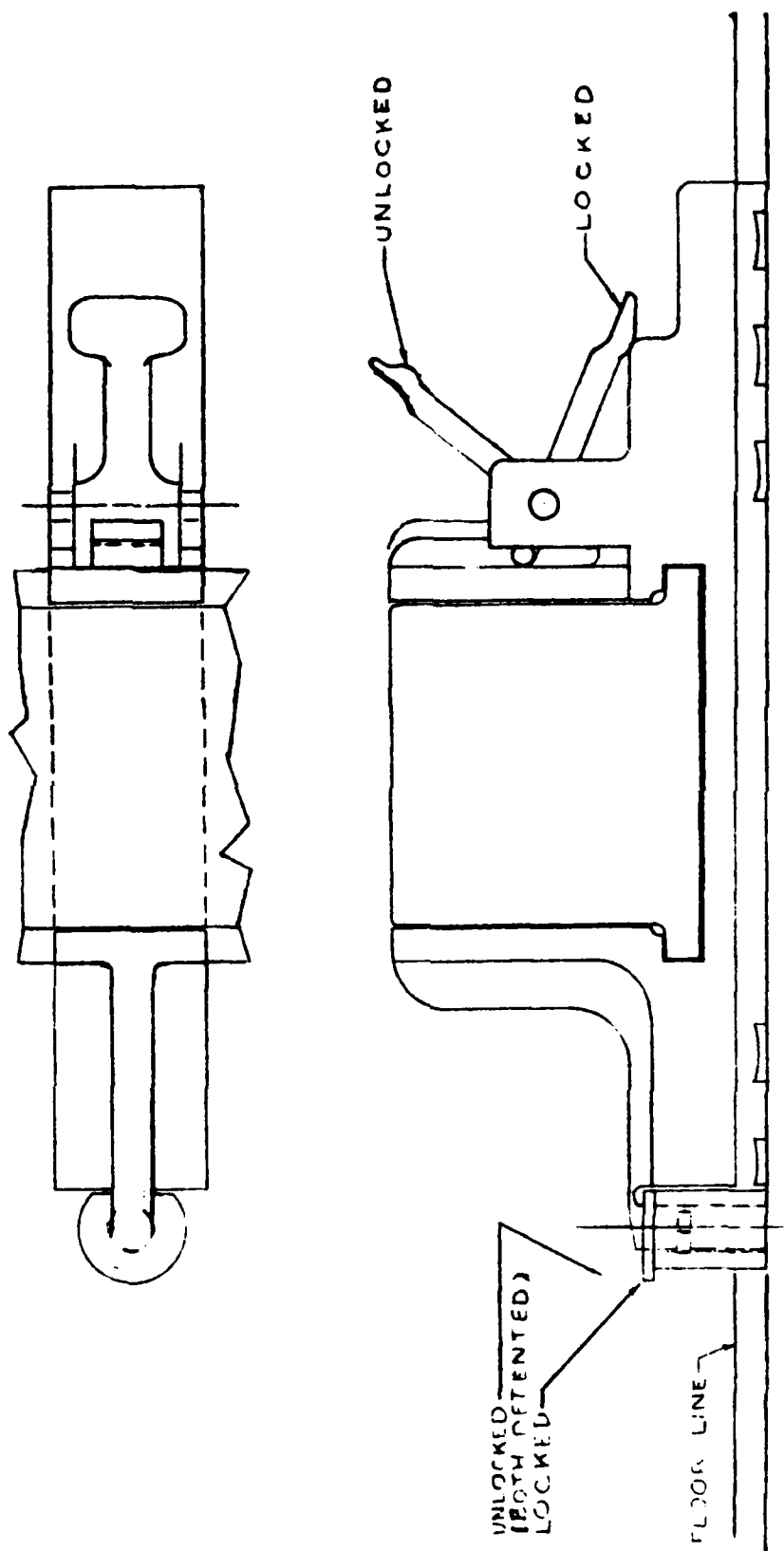


Figure 5. Details of stanchion hold-down.

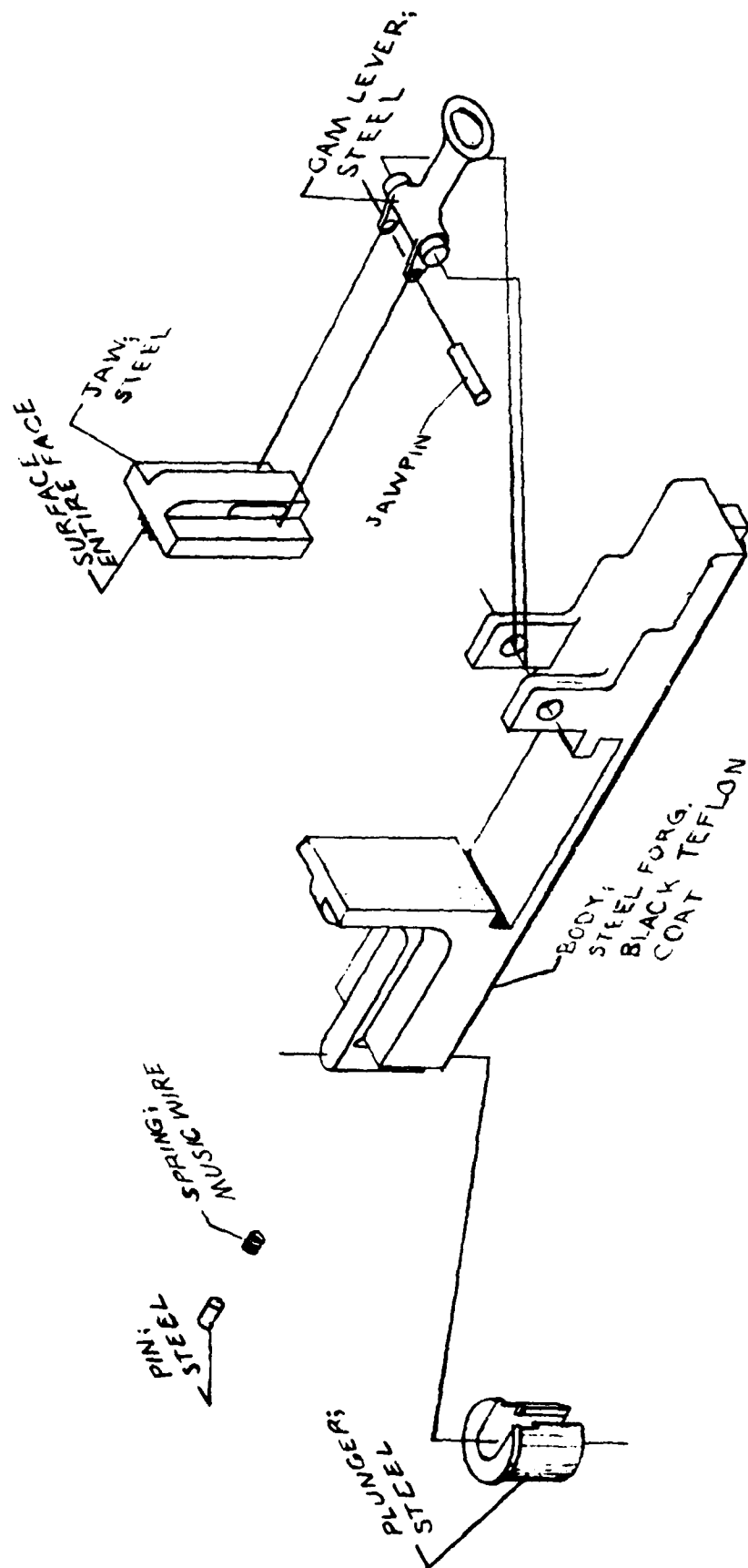
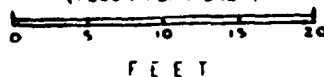


Figure 6. Litter stanchion hold-down.

LEGEND

A - Ambulatory Seating
 C - Closet/Storage
 G - Galley/Food Service
 L - Litter Patient
 MC - Medical Crewmember
 MED KIT - TATS Unit
 S - Litter Stanchion
 Exit
 X - Oxygen/Electrical Module

SCALE
 (FLOOR PLAN ONLY)



FORWARD SECTION

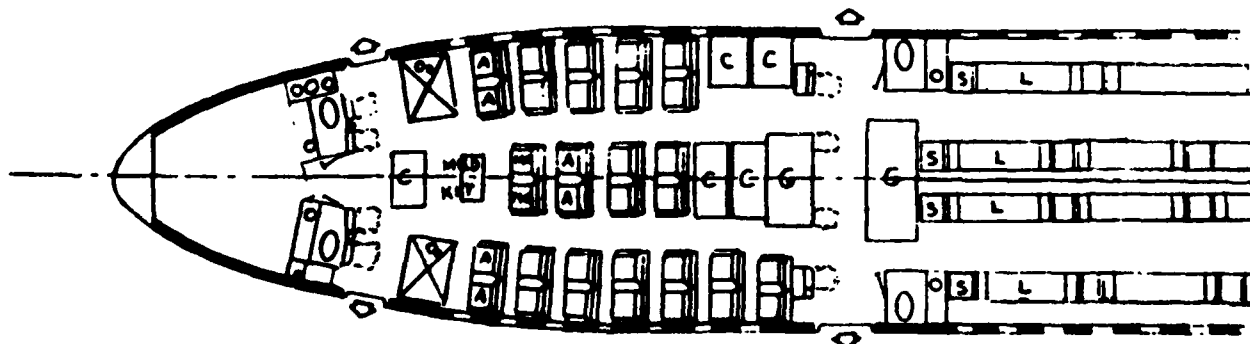


Figure 7. Medevac layout of DC-10 aircraft.

(Cont'd. on facing page)

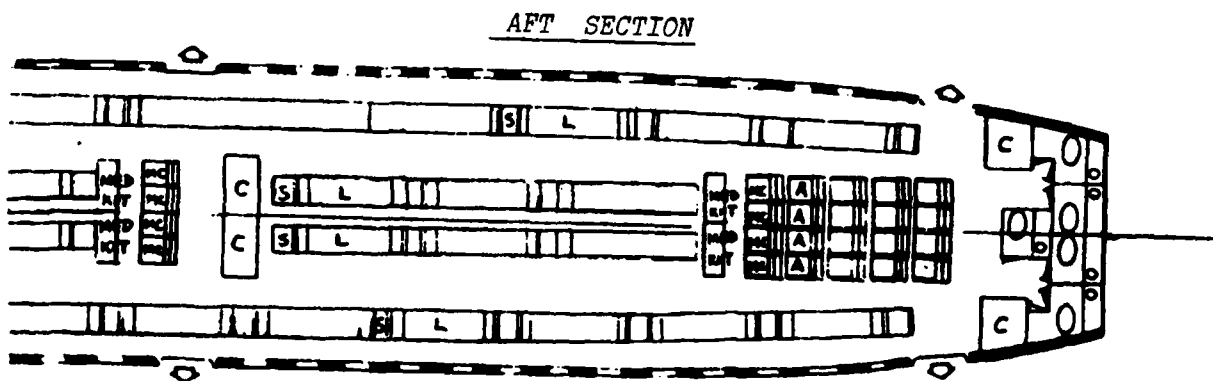
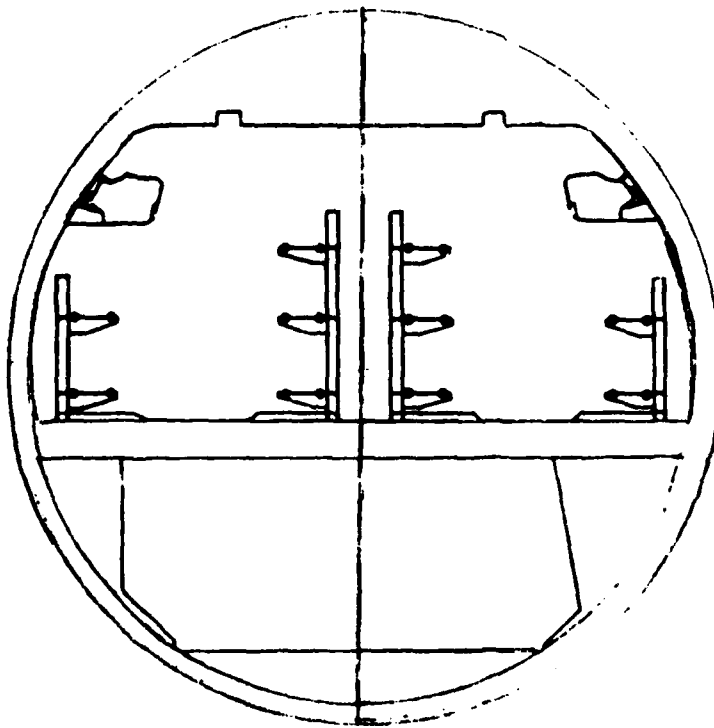


Figure 7 (Cont'd.)

LEGEND

A - Ambulatory Seating
 C - Closet/Storage
 G - Galley/Food Service
 L - Litter Patient
 MC - Medical Crewmember
 MED KIT - TATS Unit
 S - Litter Stanchion
 Exit
 X - Oxygen/Electrical Module

SCALE
 (FLOOR PLAN ONLY)



FORWARD SECTION

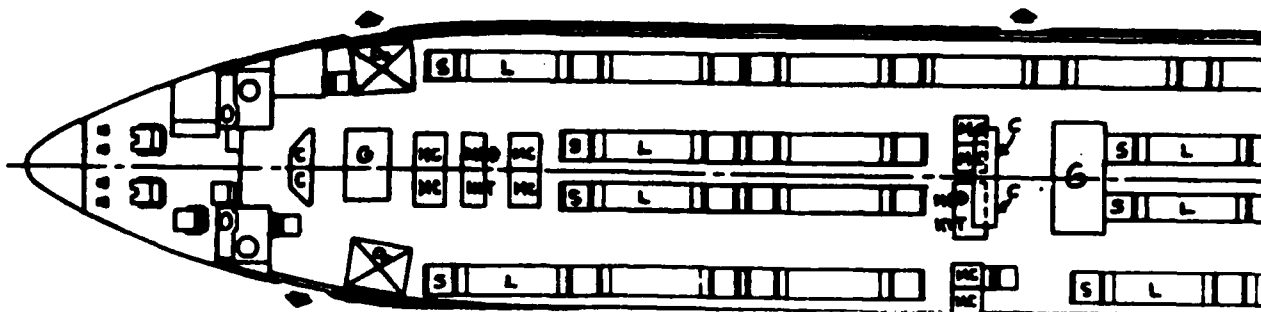
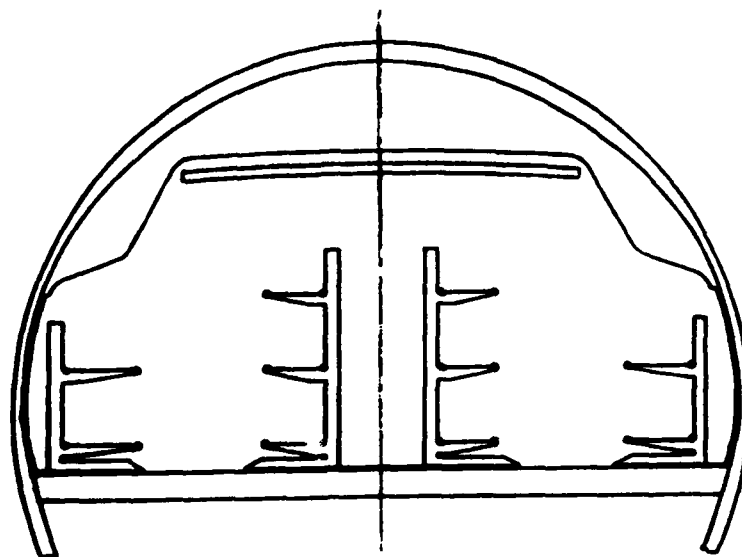


Figure 8. Medevac layout of L-1011 aircraft.

(Cont'd. on facing page)



AFT SECTION

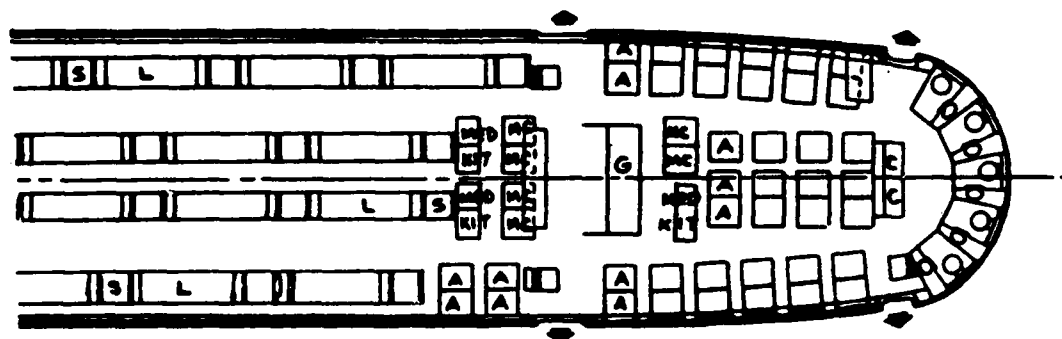


Figure 8 (Cont'd.)

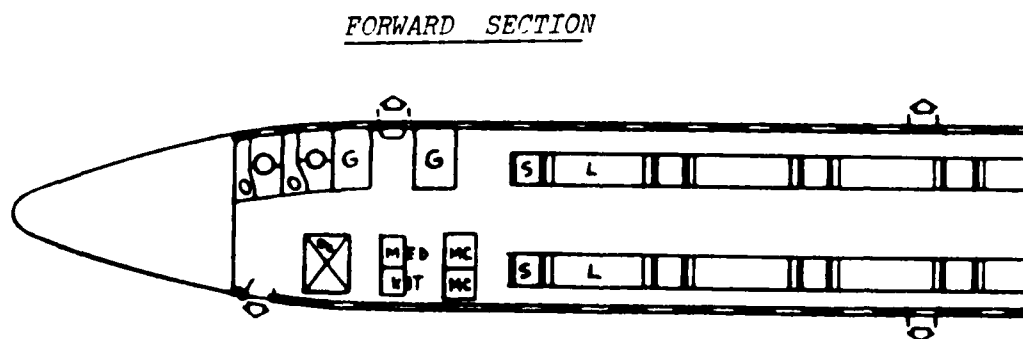
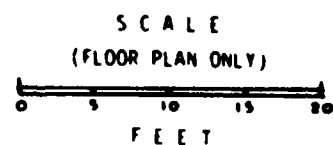
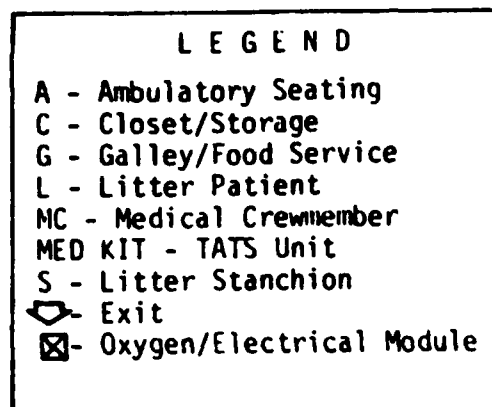
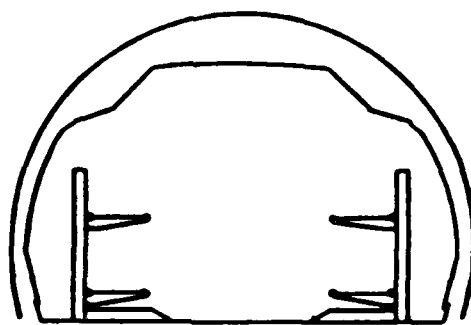


Figure 9. Medevac layout of B-707 aircraft.

(Cont'd. on facing page)



AFT SECTION

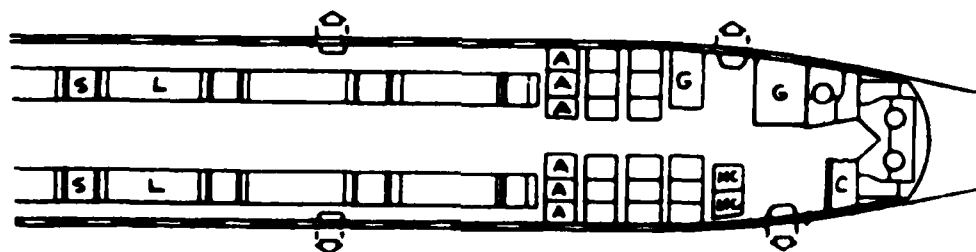


Figure 9 (Cont'd.)

LEGEND

A - Ambulatory Seating
 C - Closet/Storage
 G - Galley/Food Service
 L - Litter Patient
 MC - Medical Crewmember
 MED KIT - TATS Unit
 S - Litter Stanchion
 Exit
 X - Oxygen/Electrical Module

SCALE
 (FLOOR PLAN ONLY)



FORWARD SECTION

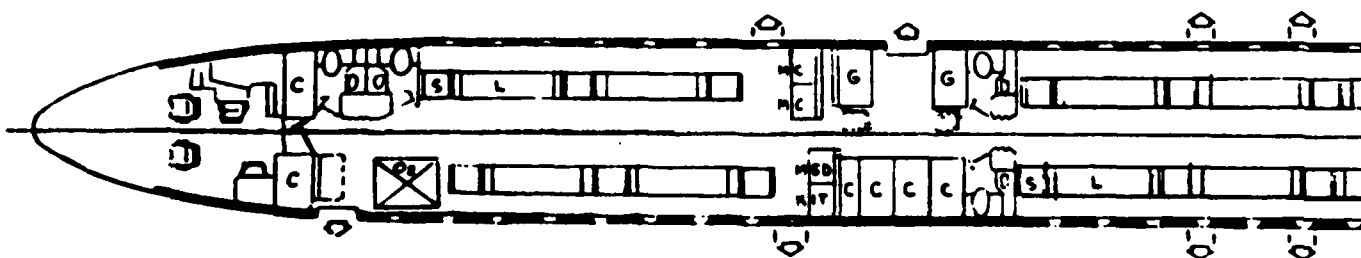
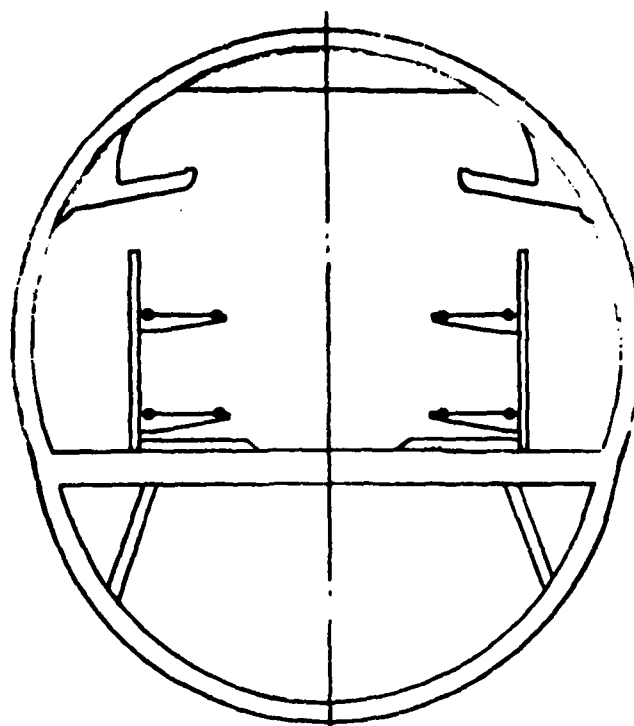


Figure 10. Medevac layout of DC-8 aircraft.

(Cont'd. on facing page)



AFT SECTION

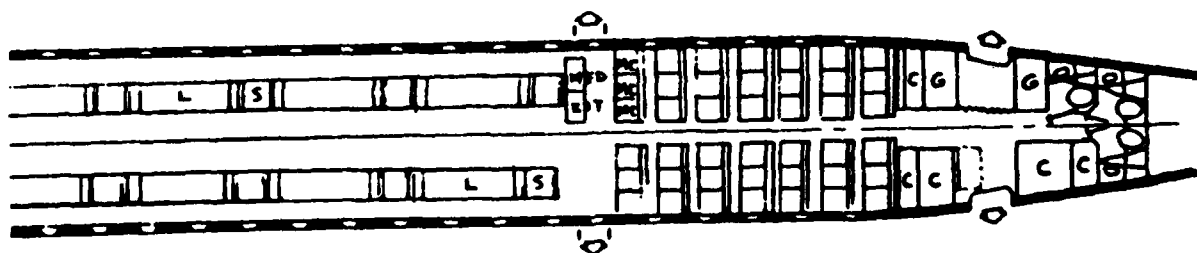
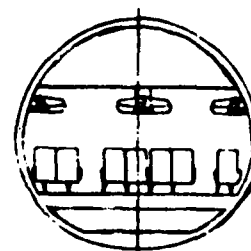
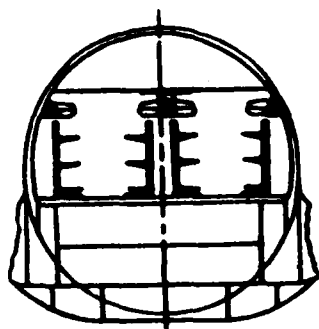


Figure 10 (Cont'd.)

LEGEND

A - Ambulatory Seating
 C - Closet/Storage
 G - Galley/Food Service
 L - Litter Patient
 MC - Medical Crewmember
 MED KIT - TATS Unit
 S - Litter Stanchion
 Exit
 ☒ - Oxygen/Electrical Module



FORWARD SECTION

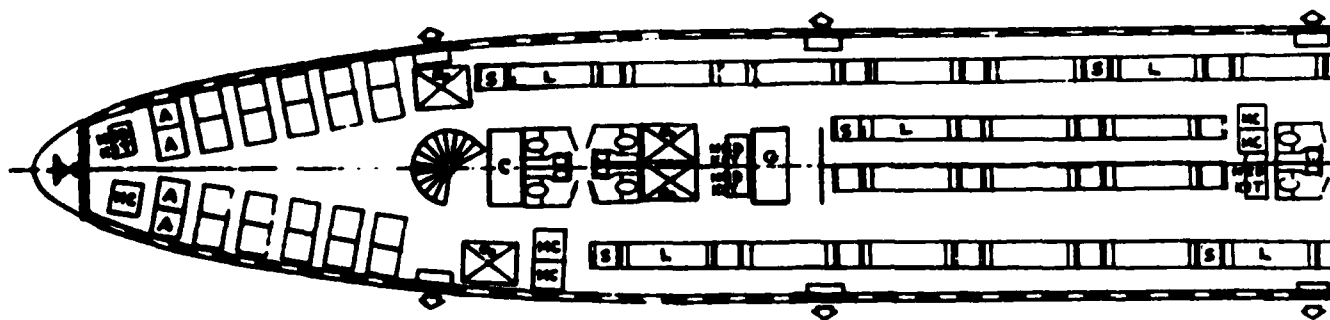
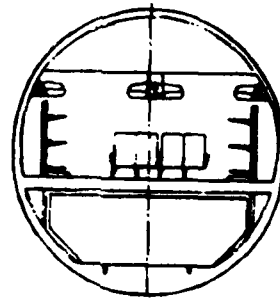


Figure 11. Medevac layout of B-747 aircraft.

(Cont'd. on facing page)



AFT SECTION

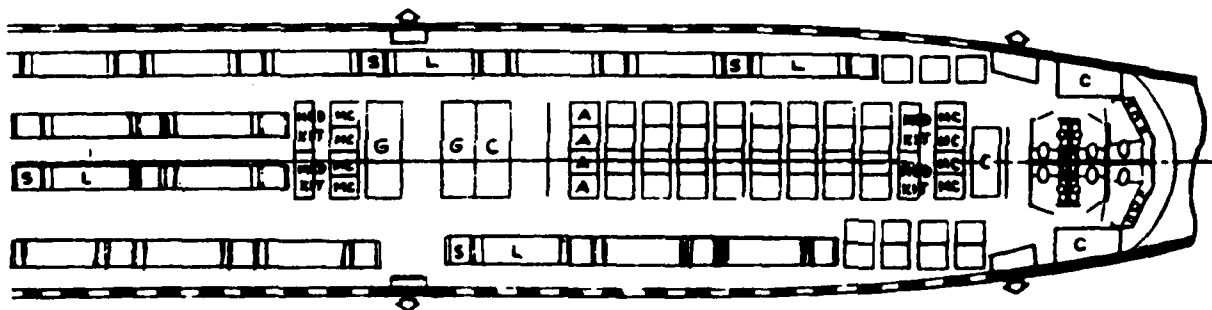


Figure 11 (Cont'd.)

APPENDIX A: EXHIBITS 1 AND 2

APPENDIX A

EXHIBIT 1:

VERTICAL MEMBER COLUMNAR BUCKLING ANALYSIS FOR LITTER SUPPORT SYSTEM

From Article 9-3: "Buckling of Long Straight Columns" (Higdon et al., p. 507 *)--

Euler's Equation for Buckling Load:

$$P_{cr} = \pi^2 EI/L^2$$

in which

P_{cr} = Euler's buckling load,
 E = Young's modulus,
 L = Effective length, and
 I = Moment of inertia about the axis on which buckling occurs.

Assuming that the lower end of the member is cantilevered and the upper end is free, the effective length, L , becomes $2L$, actual (Higdon et al., p. 514, Fig. 9-7 *). Therefore, the critical load is expressed as:

$$P_{cr} = \pi^2 EI/4L^2 \text{ actual.}$$

MODEL LSS-1

The actual length of the vertical member is 67 in. The moments of inertia about the X and Y axis, (as shown in Fig. A-1) are $I_{xx} = 1.495101089 \text{ in.}^4$ and $I_{yy} = 1.030995966 \text{ in.}^4$, respectively. Assuming the vertical loads all act as a force centered on the centroid at the top of the member, the critical loads for buckling about the X and Y axes are:

$$P_{cr_x} = 8546.613132 \text{ lb, and}$$

$$P_{cr_y} = 5893.597247 \text{ lb.}$$

*Higdon, Archie, et al. Mechanics of Materials, 3rd ed. New York: Wiley and Sons, 1976.

--APPENDIX A--

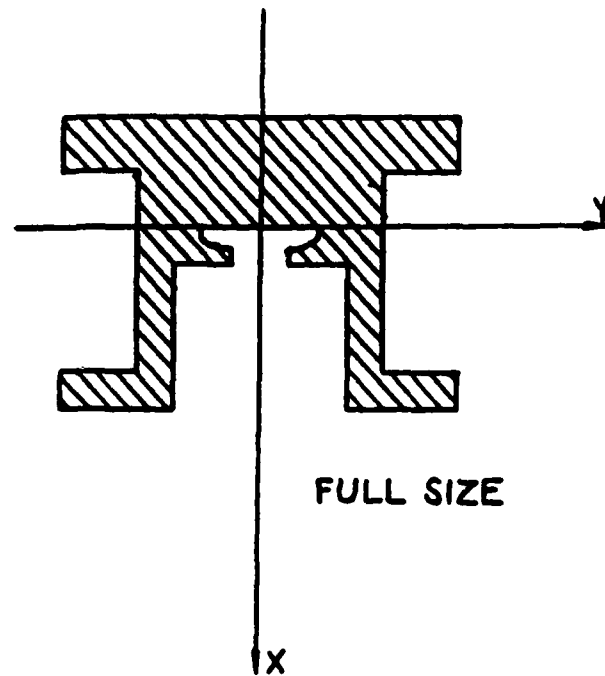


Figure A-1. Cross-section of vertical member: centroidal axes.

--APPENDIX A--

The expected vertical load is 399 lb (assuming 3 litters, each 16 lb, and each with 250-lb load, neglecting the weight of the support arm). However, with application of the MIL-SPEC #MIL-A-008865A (USAF) G Factor of 4.5, the vertical load becomes 1795.5 lb (Treat, et al.*).

Since each of the critical buckling loads is much larger than the adjusted vertical load, the vertical member can be expected to perform its task. However, the following assumptions have been made within this analysis:

1. All vertical loads could be said to act through the centroid of the vertical member.
2. All vertical loads act as if applied at the top of the vertical member.
3. The weight of the C-9 cantilever arm is neglected, and so is that of the vertical member.
4. No moments are applied to the analysis.

Another assumption is that the joint at the base of the vertical member can be made rigid enough to be considered a cantilevered joint.

MODEL LSS-2

According to the foregoing method, for the Model LSS-2 the Euler buckling loads are:

$$P_{cr_x} = 18900 \text{ lb}$$

$$P_{cr_y} = 13000 \text{ lb}$$

The expected vertical load is 1197 lb. Therefore, the load is quite small as compared with the load at which any deflection would cause buckling. Thus, the Model LSS-2 member can also be expected to perform without failure.

* Treat, R.C., et al. "Air Evacuation of Thermally Injured Patients: Principles of Treatment and Results." Journal of Trauma 4 (1980): 275-279.

--APPENDIX A--

EXHIBIT 2:

COST ESTIMATE FOR
LITTER SUPPORT ASSEMBLY
(For quantity = 10,000)

Part #1 (per Fig.A-2) - Vertical Stanchion:

Material:

Extrusion (A1) @ \$.65/ft 6.5 ft/piece (2 required)	\$8.45
--	--------

Machining & Assembly

Tooling - \$1200.	0.12
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Labor - .75 hr @ \$25/hr	18.75
--------------------------	-------

Total	\$27.32
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Estimate Range: \$25.00 - \$34.00

Part #2 - Rear Vertical Brace

Material:

Extrusion (A1) @ \$.45/ft 6.5 ft/piece (2 required)	\$5.85
--	--------

Machining & Assembly:

Labor - 0.5 hr @ \$25/hr	12.50
--------------------------	-------

Accessory Parts:

Clamp @ \$0.75 each	0.75
---------------------	------

Total	\$19.10
-------	---------

Estimate Range: \$19.00 - 25.00

Part #3 - Horizontal Footing

Material:

Extrusion (A1) @ 0.90/ft 2.0 ft/piece (2 required)	\$3.60
---	--------

Machining & Assembly:

Tooling - \$1400.	0.14
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Labor - 0.5 hr @ \$25	12.50
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Total	\$16.24
-------	---------

Estimate Range: \$15.00 - \$18.00

--APPENDIX A--

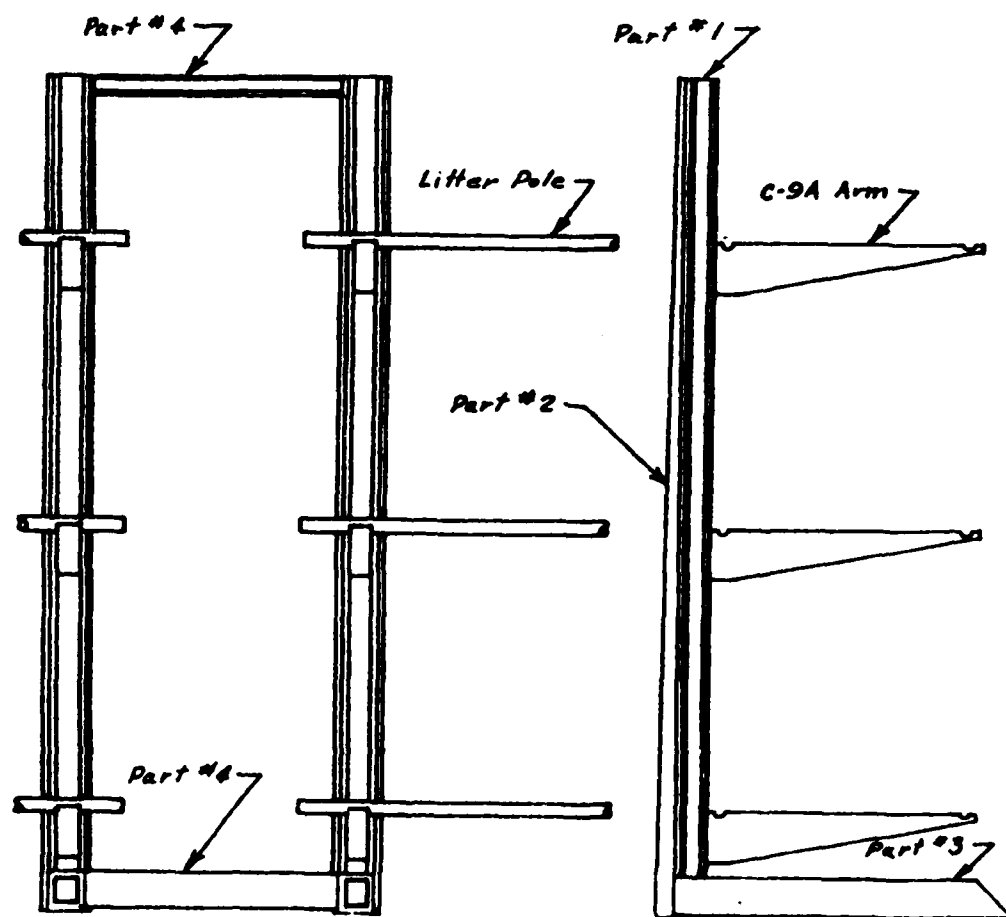


Figure A-2. Litter stanchion assembly.

--APPENDIX A--

EXHIBIT 2(Cont'd.)

Part #4 - Horizontal Brace

Material:

Extrusion (A1) @ \$0.75/ft
2.0 ft/piece (2 required) \$3.00

Estimate Range: \$2.00 - \$3.50

Frame Assembly

Material:

	<u>Estimate Range</u>
Part #1 (Vertical Stanchion)	\$25.00 to \$34.00
Part #2 (Rear Vertical Brace)	19.00 to 25.00
Part #3 (Horizontal Footing)	15.00 to 18.00
Part #4 (Horizontal Brace)	2.00 to 3.50
Welding Materials	5.00 to 5.00
	<u>\$66.00 to \$85.50</u>

Assembly Labor:

Welding 1 hr @ \$30.00 \$30.00 \$30.00

Total Assembly - Estimate Range: \$96.00 to \$115.50

ABBREVIATIONS AND ACRONYMS

AECC	Aeromedical Evacuation Control Center
APU	auxiliary power unit(s)
BRS	Bibliographic Retrieval Service
CMCHS	Civilian-Military Contingency Hospital System. A group of civilian medical treatment facilities that have contracted to make a certain number of beds and associated services available to the military, if requested to do so.
CONUS	Continental United States (does not include: Hawaii, Alaska, Puerto Rico, Virgin Islands, etc.)
CRAF	Civil Reserve Air Fleet
FARs	Federal Aviation Regulations
lb/ft ²	pound(s) per square foot
LOX	Liquid Oxygen System
lpm	liter(s) per minute
LRI	long-range international
MAC	Military Airlift Command
medevac	Air Force aeromedical evacuation system
MMS	Modular Medevac System
NaClO ₃	sodium chlorate
NaClO ₄	sodium perchlorate
NTIS	National Technical Information Service
OBOGS	Onboard Oxygen Generation System
PAX	all passenger airplanes
SON	statement of need
TATS	Therapeutic Airborne Treatment Station
TOMS	therapeutic oxygen manifold distribution system
TRIS	Transportation Research Information Service

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